MSc in Environmental Sciences, Policy and Management - MESPOM

Strategies for adaptation to climate change through microfinances: an experimental evaluation in Colombian agriculture

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María del Pilar Restrepo Orjuela

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A ti,

por tu apoyo,

tu paciencia,

por esperarme,

por permitirme perseguir este sueño

y por seguirme a donde quiera que voy.

Este logro también es tuyo.

A thesis submitted to the Department of Environmental Sciences and Policy of

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STRATEGIES FOR ADAPTATION TO CLIMATE CHANGE THROUGH MICROFINANCES: AN EXPERIMENTAL EVALUATION IN COLOMBIAN AGRICULTURE

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This thesis is submitted in fulfillment of the Master of Science degree awarded as a result of successful completion of the Erasmus Mundus Masters course in Environmental Sciences, Policy and Management (MESPOM) jointly operated by the University of the Aegean (Greece), Central European University (Hungary), Lund University (Sweden) and the University of Manchester (United Kingdom).

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:

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The growing problem of maintaining socio-economic sustainability in a changing climate has focused attention of a wide range of stakeholders on devising and delivering adaptive responses. A series of IPCC reports have emphasised that the economies of developing countries and particularly the poor would bear the brunt of climate change impacts. Farmers are highly vulnerable because of their high and direct dependency on natural resources, climate-sensitive livelihoods and lack of access to resources that they could rely on to respond successfully to shocks. Microfinance has become an increasingly used and effective tool to respond to major global challenges at the local level, including poverty and climate change. This thesis seeks to analyze the effects that the level of climate change risk and impact has on the willingness of Colombian farmers to invest, through microfinances, in strategies to adapt anticipatively to climate change. The methodology combines experimental economic games, surveys and interviews with farmers who cultivate three different crops: coffee, cocoa and citrus. The findings demonstrate that adaptation decisions depend on climate variability, the cost to implement an adaptation strategy and its benefits to cope with current hazards. Some farmers are risk takers as they prefer to face the risk of losing the harvest rather than pay the adaptation costs. Integrated pest management and beekeeping were strategies preferred under any level of climate variability, while farmers invested in crop diversification and solar dehydrators when facing higher risk of climate change. They were willing to obtain individual and associative microcredits. Microcredits awarded to small farmers in a short period of time enable them to accumulate and manage assets that make them less vulnerable. Microfinance can be more effective when combined with training and bottom-up strategies such as social networks, establishment of partnerships, collective lands and social learning that help farmers to increase their earnings, improve land productivity and promote food security.

Keywords: Adaptation, climate change, microfinances, agriculture, experimental economic games

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List of Abbreviations

CBD – Convention on Biological Diversity

CDMB - Corporation for the Defence of the Plateau of Bucaramanga (for its acronym in Spanish)

DANE – National Bureau of Statistics (for its acronym in Spanish)

EbA - Ecosystem-based adaptation

EEG – Experimental Economic Game

ENSO - El Niño-Southern Oscillation

FINTRAC – Agricultural solutions to end hunger and poverty (for its acronym in Spanish)

GEF – Global Environment Facility

GHG – Green House Gases

IDEAM - Institute of Hydrology, Meteorology and Environmental Studies of Colombia

INAP – Integrated National Adaptation Plan

IPCC – Intergovernmental Panel for Climate Change

IPM – Integrated Pest Management

MEbA - Microfinance Ecosystem-based Adaptation to Climate Change

MFI – Microfinance Institution

MSc – Master in Science

NGO – Non-governmental Organization

PNUMA – Programa de las Naciones Unidas para el Medio Ambiente (UNEP for its acronym in Spanish)

PROVIA - Programme of Research on Climate Change Vulnerability, Impacts and Adaptation

SAGARPA – Secretariat of agriculture, animal husbandry, rural development, fishing and food (for its acronym in Spanish)

UN – United Nations

UNEP – United Nations Environment Programme

USA – United States of America

USD – United States Dollar

1. Introduction

The growing problem of maintaining socio-economic sustainability in a predicted warming climate with its attendant and increasing frequency of weather extremes has focused attention of scientists and politicians on delivering new adaptive responses.

Although, adaptation and mitigation have been the two big frameworks that have led the response to this global problem, more attention should be paid to it on the national and sub-national level. Some of the key policy debates on adaptation to climate change have focused on the construction of international institutional platforms to finance adaptation, ways to increase and scale-up funding and the estimation of the costs of adaptation strategies (Agrawala and Carraro, 2010). While establishing global finance mechanisms for adaptation is important, they are not enough to address the needs for potential adaptation finance mechanisms at the local or community scale.

Bottom-up, small-scale approaches can encourage the efficient and sustainable use of financial resources in support of targeted populations to adapt to local and regional consequences of climate change. Besides, taking into account that adaptation varies according to the state of the ecosystem where it occurs as well as its social, governmental and economic context (IPCC 2003), it is necessary to identify the target population and to involve them in the diagnosis of the problems; likewise it is also important to identify the appropriate tools to allocate available financial resources to develop the solutions of such problems.

With a world-wide recognition through the UN's International Year of Microcredit in 2005 and the award of the Nobel Peace Prize to a micro-financial institution in 2006, microfinance has become an increasingly used and effective tool to respond to major global challenges, including poverty and climate change.

In 2007, the Intergovernmental Panel for Climate Change (IPCC) emphasised that the economies of developing countries would bear the brunt of climate change impacts, in particular those with the greatest levels of poverty. As the report pointed out, climate change is no longer just a general environmental issue; it will result in major stress particularly on poorer populations and humanitarian and socio-economic upheaval. There are many contextually specific factors that make the poor more vulnerable, such as settlements on marginal lands, high and direct dependency on natural resources for survival, climate-sensitive livelihoods and lack of access to resources that they could rely on to respond successfully to shocks and stresses (Ellis, 2000; Moser, 1998). In this sense, reducing the vulnerability of poor people will counter such stresses, as poverty is both a condition and a determinant of vulnerability (Hammill *et al.*, 2008).

In this context microfinance plays an important role in helping the poor to adapt to climate change. This financing approach allows poor individuals and households to have access to basic financial services and provides them with the capabilities to become less susceptible and be able to cope with shocks and stresses (Hammill *et al.*, 2008). Through microfinance the world's poor and the more vulnerable sections of the community can accumulate and manage assets on a sustainable basis.

This will develop protection against terminal damage to those communities by stabilising consumption regardless of the economic situation (Agrawala and Carraro, 2010; Mahmud, 2003). The logic behind this scheme is that the more assets and capabilities they have, the less vulnerable they are (Moser, 1998; Swift, 1989; Hammill *et al.*, 2008).

Microfinance has been demonstrated to be a suitable tool to reduce poverty-related vulnerabilities and so its implementation is deserving of greater attention and investment. In addition, most of the world's poor are naturally more vulnerable since livelihoods are often almost completely dependent on natural resources and ecosystem services (Ferraro and Kiss, 2002; Hills *et al.*, 2013). To reduce risk and improve livelihoods, microfinance can be used to preserve and enhance those key environmental services. This favours both the ecosystems and the communities to adapt to impacts of climate change (Hills *et al.*, 2013).

In order to promote adaptation of ecosystems and communities to climate change, this thesis is developed jointly with a Colombian microfinance institution named Crezcamos[1]. Crezcamos is one of six microfinance institutions participating in a climate change project entitled Microfinance for Ecosystem-based Adaptation (MEbA), implemented jointly by the United Nations Environment Programme (UNEP) and Frankfurt School in the Andean region of Colombia and Peru. The MEbA project seeks to provide microfinance services to vulnerable small-scale farmers in the Andes to enable them to invest in activities related to maintaining ecosystem sustainability while improving their income as well as their adaptive capacity to climate change (PNUMA, 2013). Ecosystem-based adaptation (EbA) uses biodiversity and ecosystem services in an overall adaptation strategy to help people adapt to the adverse effects of climate change (CBD, 2009). By incorporating the microfinance and EbA components, both ecologic and economic resilience can be increased since microfinance could be more effective not only when alleviating poverty but also when tackling those drivers that raise the risk of having shocks and stresses and increase vulnerability (Hills *et al.*, 2011).

The MEbA project published a guide of 40 systemized Ecosystem-based Adaptation options that could be implemented in the Andean region of Colombia through microfinance services and products (PNUMA, 2013). Crezcamos is planning on developing microfinance products, which are based on some of the EbA options presented in the guide, and that promote sustainable agriculture in the Santander Region. This MSc Thesis is developed on the context of this initiative by contributing to analyze the accuracy of certain strategies to be implemented in the Santander Region. Therefore, the overall objective of this MSc Thesis is to analyze the willingness of

[1] http://www.crezcamos.com/

Colombian farming communities to invest in strategies to adapt anticipatively to climate change. This objective is achieved by answering three research questions: i) how potential changes in climate variability, as a result of climate change, influence the willingness to invest in adaptation strategies by farmers; ii) what adaptation strategies are the most relevant to adapt to climate change in these communities; and, iii) what is the willingness of farmers to implement these strategies through microfinance products.

This document presents, in the third chapter, the literature review that states the relevance of investing in adaptation options to climate change in Colombian agricultural systems. The research questions will be addressed by conducting interviews, surveys and experimental economic games whose descriptions are explained in the fifth chapter. The findings of the methodology are presented and analyzed in Chapter 6. The implications, limitations and relevance of the results are discussed in Chapter 7. Finally the conclusions of the thesis are presented in the last chapter.

2. Objectives

2.1. Overall Objective

To analyze how the risk of experiencing climate change conditions influences the willingness of Colombian farming communities to invest in strategies to adapt anticipatively to climate change.

2.2. Specific Objectives

1. To identify which of the adaptation strategies proposed by UNEP should be implemented considering farmer's perception on its potential on reducing the impacts of climate change on agriculture in Rionegro.

2. To create a baseline of farmers' current access to microfinance services and their principal reason for using those services.

3. To understand the ability of rural farmers in the Santander Region of Colombia to implement adaptation strategies proposed by UNEP through the use of microfinance products.

3. Literature Review

3.1. Adaptation to climate change in agriculture

Agriculture is one of the most sensitive sectors to the impacts of climate change. Floods, droughts and changes in irrigation systems and supplies are some of the problems that most affect this sector (Escobar, 2013; Speranza and Feres, 2010; Thomas *et al.*, 2007; Abelson, 1992). Thus, adaptation has become one of the policy responses to tackle such vulnerability and reduce the risk of damage (Ramírez-Villegas *et al.*, 2012; IPCC, 2007). Many adaptation strategies have been implemented in agricultural systems. These have ranged from small scale, such as diversification of seeds or insurance, to large scale such as water management systems and changes in regional or national policy (Challinor, 2007; Thomas *et al.*, 2007; Burton, 2004; Bradshaw, 2004).

Adaptation involves making adjustments in the processes or structures of ecological, social or economic systems as a response to actual and predicted effects of climate change (IPCC, 2003). Adaptation in agriculture is more complex because it involves making changes in all these components since it is aimed at people who are economically dependent on land use. The goal of adaptation is that through these adjustments, the community can moderate the potential damage or even benefit from opportunities associated with climate change (IPCC, 2003). However, some authors (Smit *et al.*, 1999; Smit and Skinner, 2002; Bradshaw *et al.,* 2004) have distinguished many types of adaptation in agriculture according to purpose, times, scale and responsibility.

The purpose behind an adaptation strategy leads to an adaptation that is undertaken spontaneously and *autonomously* or consciously and *planned* (Smit and Skinner, 2002). The former is usually implemented by the private sector or individuals who, faced with such shocks, decide autonomously to change their scheme to mitigate the effects of climate change. Its benefits are usually private (Bradshaw *et al.*, 2004). For instance, in agriculture, peasants could adapt to climate change by choosing the crops they may grow using a large variety of seeds that are more resistant to higher temperatures, droughts or flooding (Abelson, 1992).

On the other hand, within the public sector and socio-economic systems, adaptation tends to be consciously and centrally planned, as it is usually part of governmental programs or multisectoral schemes (Smit *et al.*, 1999). This type of adaptation seeks to enhance the adaptive capacity of an economic system, encouraging adaptation for all the members (Bradshaw *et al.*, 2004; Escobar *et al.*, 2013). Agriculture is a good example to which this strategy can be applied as it motivates all members of a community to follow a specific adaptation strategy, such as crop diversification.

Timing in adaptation refers to the point at which the adaptive response is undertaken. *Anticipatory* strategies are those which are implemented before the shock in order to mitigate its impacts. Other adaptations are *con-current* as they are implemented during the shock, while others are *reactive* responses (Smit and Skinner, 2002; Bradshaw *et al.*, 2004). However, some adaptation strategies can fall into more than one of these categories. For instance, if a farmer experiences droughts every year, he or she may plan to change their agricultural practices in the future to cope with the risk from droughts. In this case, the response is reactive and anticipatory at the same time (Abelson, 1992). For this reason, it is important to consider the duration of the strategy.

Adaptation responses can be *tactical* when they apply in the short-term or *strategic* when their scope is for longer term (Smit *et al.*, 1999; Smit and Skinner, 2002). Although tactical adaptations can be applied during one season to deal with climate conditions, they also can include selling of livestock, asking for a short-term loan, and provisional trades. Strategic responses go beyond this and imply structural changes in the agricultural practices or in the production process of a company, land use, crop diversification or insurance (Bradshaw *et al.*, 2004). Microfinance favours adaptation in both tactical and strategic scenarios since it provides access to financial services, such as microcredits, loans and insurance; advantages that will be explained in the next section.

In terms of scale, adaptation in agriculture can extend from a plant or a farm to a whole region. Consequently, the responsible participants might change according to the spatial scale - farmers, producers, private sector, local governments- (Bradshaw *et al.*, 2004). Table 1 shows how the attributes explained generate different responses to adaptation. A good adaptation strategy involves knowing the status of many of these attributes of the place where it is expected to occur: local policies, institutions, the affected population, uncertainties, natural processes, the scope of the strategy and opportunities to adapt.

Table 1. Attributes for different types of adaptation

General Differentiating Concept or Attribute	Examples of Terms Used
Purposefulness	Autonomous ↔ Planned Spontaneous ↔ Purposeful Automatic ↔ Intentional Natural ↔ Policy Passive ↔ Active Strategic
Timing	Anticipatory ↔ Responsive Proactive ↔ Reactive *Ex ante* ↔ *Ex post*
Temporal Scope	Short term ↔ Long term Tactical ↔ Strategic Instantaneous ↔ Cumulative Contingency Routine
Spatial Scope	Localized ↔ Widespread
Function/Effects	Retreat - Accommodate - Protect Prevent - Tolerate - Spread - Change - Restore
Form	Structural - Legal - Institutional - Regulatory - Financial - Technological
Performance	Cost - Effectiveness - Efficiency - Implementability - Equity

Source: Smit *et al.*, 1999

3.1.1. Adaptive capacity of agricultural systems

The IPCC defines *adaptive capacity* as "the potential or ability of a system, region, or community to adapt to the effect or impacts of climate change" (IPCC, 2003; 881). In agriculture, the impacts of climate change to which communities must adapt not only include the average annual climate conditions, but also its variability and the magnitude of extreme weather events (Smit *et al.*, 1999; Smit and Skinner, 2002). Consequently, adaptive capacity in agricultural systems must implicitly incorporate the ability to adapt to inter-annual events including predicted increasing frequency of extreme events due to climate change.

To strengthen adaptive capacity in agricultural systems, it is essential to tackle the vulnerability to specific climate stimuli through non-climatic factors such as economic conditions, other aspects of the environment, society, politics and technology (Smit and Skinner, 2002; IPCC, 2003). Smit and different stakeholders in Canada identified four categories within the non-climatic factors in which adaptation can be undertaken in agriculture: i) technology developments, ii) government programs and insurance, iii) farm production practices and iv) farm financial management. Table 2 shows the examples of adaptation options for each category. These categories are widely defined and one might think that they apply to almost any agricultural system; however, the particularities of each agricultural system would change the way in which these categories can be undertaken. For instance, in a developing country as Colombia where the access to technology is low, the adoption of technology will be limited to the financial situation of farmers who probably will adopt a less advanced technology.

Usually, technological developments involve considerable financial investments in research targeted to deliverables such as purchase of equipment, human capital and implementation and the exploitation of the new technology.

Once implemented, continued support will deliver significant potential benefits at larger economic scales beyond the local community (Smit and Skinner, 2002). In fact, if the results are positive, the same technology can be replicated in other locations subjected to the same economic conditions and climate stresses. Creation of new and more resistant seed types, software for regional climate change prediction including hydrological management are part of the technological developments in agriculture. Technology helps to deal with uncertainties, especially in climate variations (IPCC, 2007).

Farming practices are associated with changes in the operational phase through which exposure to climate-related risks is reduced. It increases the flexibility of farmers to adapt to constant variations in climate conditions as well as the efficiency of the farm (Smit and Skinner, 2002). Examples of this adaptation are the diversification of crop and livestock varieties, substitution to hybrid species, use of fallows and tillage periods, changes in the intensity of chemicals in fertilizers and pesticides, changes in capital and labour inputs, among others. It is important to highlight that many of these are aimed at reducing the economic risks associated with climate change, making the economic stability at farm-level a key attribute to reducing vulnerability. For this reason, Smith and Skinner (2002) identified one major component for financial management at farm-level.

Farm financial management uses both governmental and private resources to reduce the risk of income loss. Usually, it includes people in income stabilization programs and spreads their exposure to impacts of climate change (Smit and Skinner, 2002).

Government programs and insurance-based adaptation encompass the economic risks related to climate change. The aim of these responses is to provide farmers financial means, such as subsidies, insurance or compensation for climate-related damage, so their livelihoods will not be irreversibly affected and they will be able to stabilize their income. However, in some countries, such as Colombia, where a significant proportion of the population depends on agriculture, it is not possible to provide these universally. In these cases the private sector may play an important role by filling the gaps imposed by the limitations in government policies and regional budgets. It can bring economic resources to those communities that are not covered by governmental programs (Hammill *et al.*, 2008). Private insurance, as is shown in Table 2, is one of the multiple adaptations offered by the private sector.

Table 2. Adaptation options to climate change in agriculture

TECHNOLOGICAL DEVELOPMENTS

Crop development

- Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions.

Weather and climate information systems

- Develop early warning systems that provide daily weather predictions and seasonal forecasts.

Resource management innovations

- Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts.
- Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.

GOVERNMENT PROGRAMS AND INSURANCE

Agricultural subsidy and support programs

- Modify crop insurance programs to influence farm-level risk management strategies with respect to climate-related loss of crop yields.
- Change investment in established income stabilization programs to influence farm-level risk management strategies with respect to climate-related income loss.
- Modify subsidy, support and incentive programs to influence farm-level production practices and financial management.
- Change *ad hoc* compensation and assistance programs to share publicly the risk of farm-level income loss associated with disasters and extreme events.

Private insurance

- Develop private insurance to reduce climate-related risks to farm-level production, infrastructure and income.

Resource management programs

- Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions.

FARM PRODUCTION PRACTICES

Farm production

- Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change.
- Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change.
- Change the intensification of production to address the environmental variations and economic risks associated with climate change.

Land Use

- Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change.
- Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies.

Land topography

- Change land topography to address the moisture deficiencies associated with climate change and reduce the risk of farm land degradation.

Irrigation

- Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought.

Timing of operations

- Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.

FARM FINANCIAL MANAGEMENT

Crop insurance

- Purchase crop insurance to reduce the risks of climate-related income loss.

Crop shares and futures

- Invest in crop shares and futures to reduce the risks of climate-related income loss.

Income stabilization programs

- Participate in income stabilization programs to reduce the risk of income loss due to changing climate conditions and variability.

Household income

- Diversify source of household income in order to address the risk of climate-related income loss.

Source: Smit and Skinner, 2002

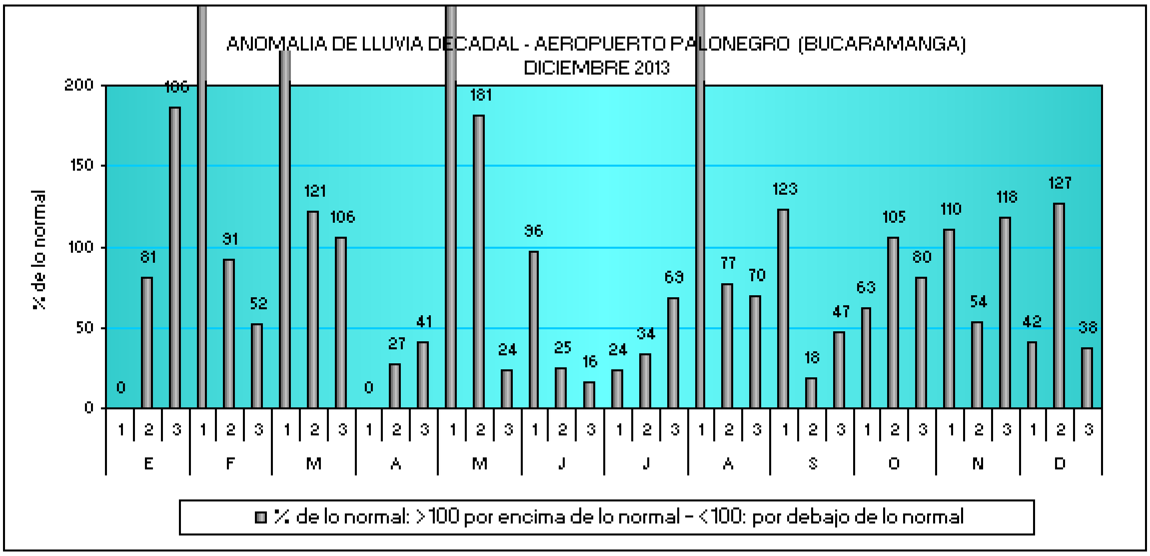
As demonstrated, all the adaptation options identified by Smit and Skinner (2002) suggest the importance and need of providing financial services, because these are the means to develop reliable adaptation strategies at multiple levels and directions. Microfinance is one of the tools most suited to implement these adaptation options in agriculture.

3.1.2. The track record of adaptation to climate change in Colombia

Colombia is a country highly vulnerable to the effects of climate change. The Fourth Assessment Report of the IPCC argues that the projected changes in climate will affect the entire socio-economic system of the country, with severe impacts on agriculture (IPCC 2007). Extreme weather events, retreat of glaciers, changes in land use, shifts in the geographic distribution and incidence of pest and diseases and increase in annual mean temperature and precipitation are the impacts that are affecting and will affect agriculture in Colombia, particularly coffee, cassava, maize, tomato and potato production (IPCC 2007; Ramírez-Villegas *et al.* 2012; Escobar *et al.*, 2013; Ibañez, 2011; Poveda and Pineda, 2009, García *et al.*, 2012).

The Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM) has measured the anomalies in monthly precipitation for the entire country. Figure 1 presents the anomalies observed in 2013 for the Santander region, which is the study area of this thesis. The anomalies are defined as the percentage of deviation from the monthly average of the period 1971-2000 (IDEAM, 2013). Values over 100% represent increased levels of precipitation and values below 100% represent less precipitation. For Santander region it is observed that during 2013, precipitation increased considerably through the year especially during the months of January, February, March, May and August in which precipitation levels doubled (closed to 200%). By contrast, during April, June and July the precipitation level fell more than a half in relation to the studied period.

Figure 1. Anomalies in monthly precipitation for Santander Region in 2013



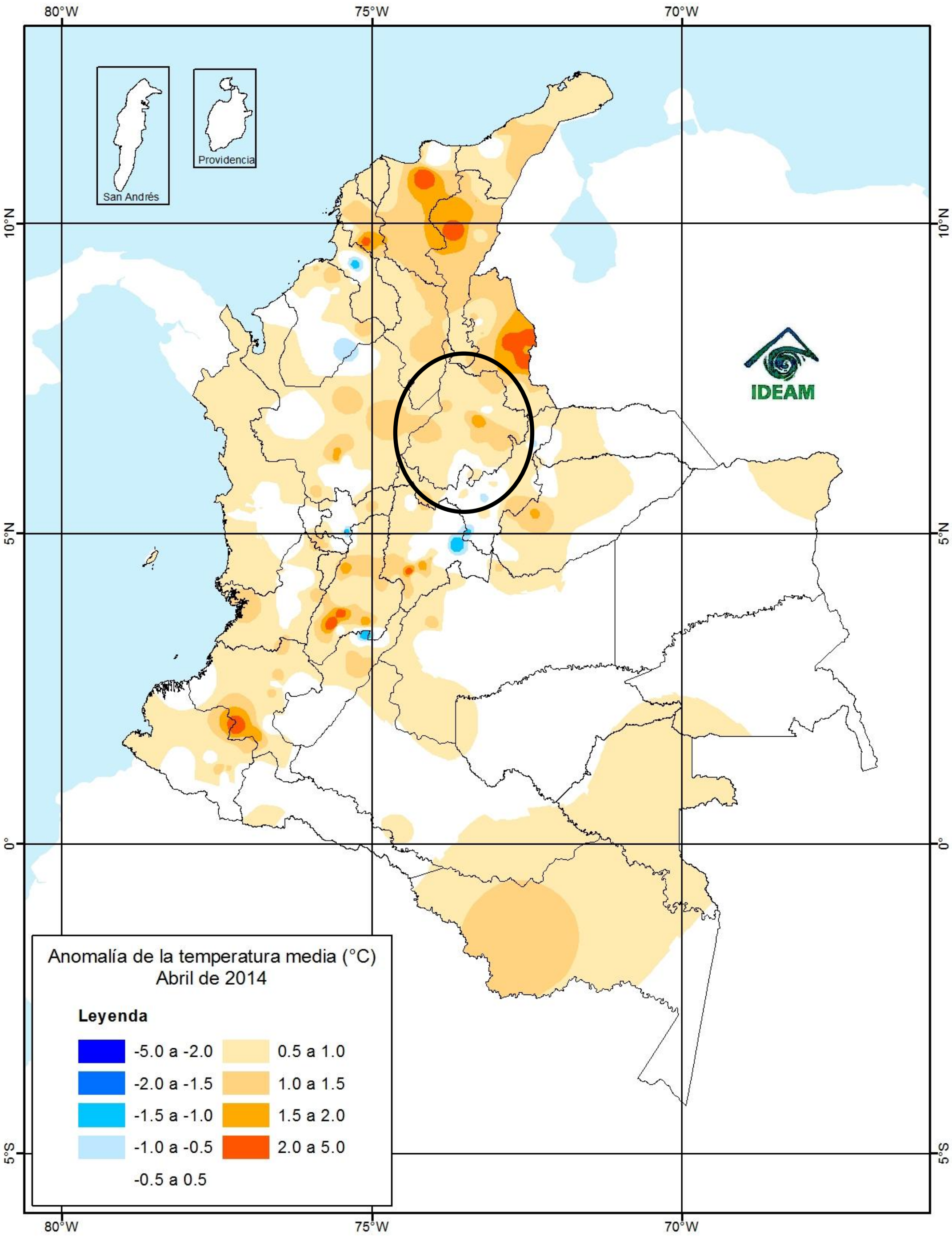
Source: IDEAM, 2013

Changes in temperature in the study area during the period 1971-2000 are presented in Figure 2. The circle area that represents Santander region shows an increase of 1-2°C in relation to the evaluated period. It provokes more exposure to sun that could lead to longer periods of droughts and can damage those crops that grow during rainy seasons. These large changes in rainfall patterns and temperature limit weather forecasting and are the consequence of a changing climate and weather phenomena such as El Niño-Southern Oscillation (ENSO) (García *et al.*, 2012; IDEAM, 2013).

On the other hand, the impact of climate change is also severe in relation to the retreat of glaciers as they are in the hydrographic basin that provides water for domestic use, agriculture and industry. 80 per cent of the water of the Western basin of the country is of glacier origin (Earls, 2009).

The consequences of the melting of glaciers in agriculture are massive. It increases the probability of extreme weather events such as long periods of drought and periods of high rainfall, flooding, landslides, water and electricity blackouts and pests (Earls, 2009, Bradley *et al.*, 2009). All of these factors affect agriculture and the livelihood of farmers. Water supply uncertainties require farmers to invest and work more in managing irrigation systems (Earls, 2009).

Figure 2. Changes in temperature in the Santander region during the period 1971-2000



Source: IDEAM, 2013 with amendments

Earls (2009) demonstrates how the Andean communities have implemented an irrigation system which synchronizes the fallow and planting stages according to the water supply for irrigation.

Through this system, farmers are able to provide the right amount of water in the correct place at the correct time. But even so, farmers cannot control major disasters such as floods and landslides, leading potentially to total crop loss.

The importance to adapt Colombian agricultural systems to climate change is that this economic sector contributes 14 per cent of the Gross Domestic Product of the country, of which 40 per cent of the total production is exported (Ramírez-Villegas *et al.* 2012). From the total employment, this sector contributes 21 per cent, where 3.7 million people directly depend on it for jobs and livelihood (DANE 2011). Thus, the implementation of adaptation strategies is crucial to the social and economic well-being of the country.

In Colombia, adaptation is framed under two projects funded by the Global Environment Facility (GEF) (Blanco, 2013): i) Integrated National Adaptation Plan (INAP) and ii) Adaptation to Climate Change in the Colombian Massif. The former focuses in high-mountain systems, insular areas and human health, and the latter seeks to incorporate adaptation to climate change in the political agenda and to reduce the emissions of greenhouse gases (GHG).

Unfortunately, there are few adaptation strategies that have been implemented in Colombia in the agricultural systems. The little knowledge about the impacts of climate change on Colombian agriculture and ecosystems has limited the planned and anticipated adaptation. In the absence of a well-planned and systematically implemented strategy, communities respond reactively and autonomously to drastic climate events.

In an effort to plan and anticipate those events, the Colombian government and educational institutions have promoted research on the impacts of climate change, especially in the worst affected areas of the country and those sectors that are more important to the economy. Through the INAP project, meteorological information for priority areas has been collected and the accuracy of weather forecasts has been improved (Blanco, 2013). With this information farmers can make adjustments to their crops and choose the variety of seeds that is more suitable for each season. The impacts on freshwater systems that serve as irrigation for cultivated areas have been also studied (García *et al.*, 2012), as well as the retreat level of glaciers in the Andes Region (Favier *et al.*, 2004; Bradley *et al.*, 2009).

The limitations of the adaptation options in Colombia demonstrate the great vulnerability to impacts of Climate Change and the urgent need to allocate financial resources to reduce the risk of big disasters. In this sense, additional measures are needed especially those that help the most vulnerable populations such as agricultural communities. Indeed, innovative and flexible methods would help stakeholders to introduce new adaptive responses that best suit the climatic problems they are facing. In addition, the few strategies implemented by the Colombian government demonstrates major capacity gaps which include lack of financial aid to mitigate the effects of climate change and lack of know-how about the effective use of financing to undertake adaptation measures.

3.2. Microfinance as an adaptation mean to climate change

Microfinance has the ability to help poor people to adapt to climate change by providing them access to basic financial services. Microfinance is the delivery of loans, savings, and insurance to poor individuals or households in order to enable them to accumulate and manage assets, establish or develop a business, protect against risks and stabilize consumption (Hammill *et al.*, 2008; Agrawala and Carraro, 2010).

But, what is interesting about microfinance is that it is not intended to serve the poorest of the poor but the "economically active poor". This means that it is designed for those who are close to the human poverty line but still have the ability to pay for small credits (Hammill *et al., 2008*). With this criterion, the microfinance institutions avoid the problem of economic assistance programs where beneficiaries become dependent on the program, which does not help them out of their poverty. Precisely, one of the aims of microfinance is to help keep people from falling below the poverty line by combining microfinance with educational and training loans, health and nutrition workshops, health loans and advice on agricultural practices (Agrawala and Carraro, 2010).

According to Agrawala and Carraro (2010), Microfinance Institutions (MFI) serve about 100 million of the world's poor as their clients, of which 90 per cent are women. MFI have been implemented all over the world, especially in those countries where the poor are the most vulnerable population to effects of climate change.

3.2.1. Microfinance in Colombia

Microfinance in Colombia is reduced to microcredit. MFI were created as a response of a governmental policy which was enhancing the development of the country through the banking expansion (Serrano, 2009). However, their field of action is limited since, by law, they are not allowed to collect money from their clients either offer insurance as it is restricted only to insurance companies (Serrano, 2009). This means that microcredit is the principal financial product offered by MFI, limiting the access of poor to saving accounts, self-insurance among other services.

However, the opportunities to finance the agricultural sector are better. In 2008, Agricultural Bank, the government bank that is aimed to provide credits to small farmers, participated with 55 per cent of the total of microcredits in the financial market in Colombia (Serrano, 2009). This big participation demonstrates the demand and need for those financial services from the agricultural sector and suggests the expansion and diversification of the portfolio of the financial products offered to agricultural producers.

With this participation in microfinance, Colombia is creating a good business environment to promote microfinance, whence ranks fourth in Latin America with 56 points and has generated a penetration rate of microfinance into the financial market of 21 per cent, as is shown in Table 3 (Pedroza, 2012).

Despite the big demand for microcredits from farmers, there is no evidence that they have been used to mitigate the effects of climate change. Barbosa-Arias (2005) argues that only 18 per cent of the total credits awarded by Agricultural Bank in 2004 were addressed to financing agricultural production mainly of rice, cotton, maize, oil palm, sugarcane and plantain. According to Pedroza (2012), there are 39 Microfinance Institutions in Colombia which offer microcredits at an average of US$ 1,049. The PNUMA (2013) (United Nations Environmental Program UNEP, for its initials in Spanish) has identified some institutions that are offering, particularly, MFI to farmers to cope with the effects of climate change in Colombia: Crezcamos, BancaMía and Contactar.

Table 3. Penetration of microcredit in Latin America by country in 2011

PAÍS	POBLACIÓN ESTIMADA 2010[1]	FECHA ENCUESTA DE HOGARES	Nº DE PERSONAS-CATEGORÍA OCUPACIONAL: PATRÓN Y CUENTA PROPIA[2]	Nº DE CLIENTE DE MICROCRÉDITO 2011[3]	PENETRACIÓN MICROFINANZAS % 2011[4]	CRÉDITO TOTAL/ PRODUCTO INTERNO BRUTO % 2011[5]
Argentina	140.412.376	2009	5.106.817	40.107	0,8	24,3
Bolivia	9.929.849	2007	1.784.357	857.644	48,1	44,9
Brasil	194,946.470	2009	23.200.818	2.376.018	10,2	48,5
Chile	17.113.688	2009	1.551.949	447.228	28,8	68,7
Colombia	46.294.841	2009	8.777.605	1.842.979	21,0	44,1
Costa Rica	4.658.887	2009	537.737	66.467	12,4	42,8
Ecuador	14.464.739	2010	2.995.188	794,375	26,5	33,9
El Salvador	6.192.993	2010	839.732	243.895	29,0	4,8
Guatemala	14.388.929	2010	1.803.555	558.953	31,0	33,3
Honduras	7.600.524	2010	1.414.802	168.166	11,9	49,6 [*]
México	113.423.047	2008	10.405.844	4.103.862	39,4	20,1
Nicaragua	5.788.163	2005	745.728	241.028	32,3	32,9
Panamá	3.516.820	2010	447.022	11.759	2,6	98,4
Paraguay	6.454.548	2010	1.133.927	194.599	17,2	31,0 [*]
Perú	29.076.512	2009	6.556.695	2.507.021	38,2	24,2 [*]
República Dominicana	9.927.320	2009	1.665.088	303.641	18,2	19,5
Uruguay	3.368.786	2010	424.811	12.968	3,1	24,1
Venezuela	28.979.857	2007	7.861.603	44.802	0,6	29,9
TOTAL	556.538.349		77.253.278	14.815.512	19,2	

Source: Pedroza, 2012

3.2.2. What should Colombia do to adapt its agricultural systems to climate change?

As there are many drivers that affect the Colombian agriculture, many responses should be applied to overcome the impacts of climate change. These responses should combine economic, social and ecosystem adaptations. Therefore, the proposal of this literature review is the implementation of microfinance in adaptation to climate change.

The UNEP (2013) has identified many possible adaptation strategies in Colombia associated to the susceptibility of ecosystems that could be implemented through microfinances, such as sustainable management of land and water, reduction of disaster risk, establishment of diverse and more resilient agroforestry systems, among others.

MFI as insurance could allow farmers to protect against risks, such as hurricanes, landslides, flooding or earthquakes. Elbaz (2007) even proposes the creation of weather derivatives or parametric insurance in Colombia. It is new microfinance services which, unlike insurance contracts, allow farmers to protect against minimal changes in climate that can result in large losses in agricultural production. Weather derivatives are a financial contract where farmers would receive a fixed amount of money when meteorological conditions as temperatures, rains, wind and snowfall exceed significantly [2] the estimated daily average. For instance, if the precipitation exceeds by 10 per cent the limit established by the insurance company, the company will pay 10 per cent of the total production. This type of insurance could reduce the risk of producers of maize and cotton to increasing precipitation as these crops are the most affected by changes in rainfall in Colombia (Suárez-López, 2008).

On the other hand, Feola (2013) claims that the challenges for Colombian agricultural rise with the free trade agreement between Colombia and United States, which began to be effective in 2012. Colombian farmers not only should adapt to climate change but be efficient enough to compete with producers from the United States, mainly in poultry, cereals, pork meat and beans. In this sense, Feola (2013) highlights that adaptation in Colombian agriculture will be determined by its economic performance in national and international markets as well as the level of investment in the agricultural practices.

[2] Usually, the insurance companies establish the minimum variability above which the insurance might be paid (Suárez-López, 2008).

Ramírez-Villegas *et al.*, (2009) identify adaptation measures for Colombian agriculture to face the expected impacts of climate change. They suggest the creation of subsidies and agricultural insurance for producers in the high-mountains who are facing the reduction of water supply as a consequence of melting glaciers. Structural changes are also needed to improve the efficiency of water management and irrigation systems. Financial investment in the conservation of moorlands, wetlands and rain forests would increase the water supply and the ecosystem services they provide (Escobar *et al.*, 2013).

In order to tackle the challenges identified in the development of the Colombian agriculture and its difficulties on facing climate change, this thesis proposes to undertake the implementation of the adaptation strategies proposed by PNUMA (2013) since they are aimed at i) reducing the pressure over the ecosystems and the services they provide, ii) increasing the social and economic resilience of vulnerable communities to climate change, iii) reducing risks associated to climatic events in agriculture, iv) protecting, restoring and using natural resources in a sustainable way and v) having a positive impact on the economy of farmers in the short-term.

By determining which of the UNEP's strategies should be adopted by farmers that enable them to adapt to climate change impacts, this thesis might be contributing to the adaptation work UNEP has been doing in Latin America. Particularly, UNEP has been developed the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) that seeks to promote communication between the scientific community, decision-makers and users in order to improve the availability and accessibility of knowledge to the people that need it most (PROVIA, 2014). Thereby, this thesis proposes a methodology that includes farmers in the construction of knowledge related to vulnerability, impacts and adaptation to climate change and provides solutions to decision-makers to the benefit of those agricultural populations.

4. Study area

The study area of this thesis is the Municipality of Rionegro that belongs to the Santander Region in Colombia. Figure 3 presents the map of the study area and the location of the three workshops conducted with small farmers of three different crops: coffee, cacao and citrus.

Figure 3. Map of the study area

Source: Alcaldía de Rionegro (2014) with ammendments

The Municipality of Rionegro is located at 690 meters over the sea level where the temperature ranges between 19-25˚C and there is a mean annual precipitation of 1,500mm (Rodríguez, 2012). The rainy season usually occurs during April, May, October and November, while the dry season is January, February, June, July and August (Rodríguez, 2012). Within the boundaries of Rionegro, three rivers create natural corridors: Black, River, River of the Holy Spirit and Lebrija River. Rionegro had a total population of 27,775 according to the last census performed by DANE in 2012 (DANE) where the bulk of the population is between 10 and 19 years old.

This Municipality was selected by the microfinance institution of Crezcamos because of its high demand for financial services from small farmers and the increasing effects of climate change faced by those farmers in the lasts years. The principal economic activity is agriculture followed by livestock where Rionegro contributes the most to the production of coffee and cocoa of the Santander Region (Rodríguez, 2012).

5. Methodology

Since the aim of the MSc Thesis is to determine the most appropriate ecosystem-based adaptation strategies that could be supported through microfinance, it is important to understand the perceptions of Colombian farmers of implementing such strategies in their communities. To achieve that aim, the methodology of this research used experimental economic games (EEGs), surveys and interviews with farmers from an Andean municipality of Colombia in the Santander region: Rionegro. The community was selected by the work team of the MFI Crezcamos in the frame of their project to implement adaptation strategies based on ecosystems.

Through the interviews and surveys, a baseline is built on current access to financial services for farmers. Besides, information necessary to design and run the EEG is collected, such as the frequency and intensity of various weather events, such as precipitation, drought and frost and how these events affect crop production. Other information regarding economic variables, useful for the EEG, is also collected, such as the average of annual profits in different types of crops and crop losses due to extreme weather.

EEG helps understand the behaviour of farmers and their decision making process when facing the impacts of climate change. Furthermore, the surveys complement the information obtained in the EEGs since they were carried out at the end of the games with the same participants. At the end, the information of the three methods is used to characterize the scenario where the strategies could be potentially implemented. Qualitative and statistical analysis is performed to analyze the results from the surveys and the EEGs. A diagram with the description of the three methods is presented in Figure 4.

Figure 4. Methods used to achieve the research questions

Experimental Economic Games (EEGs)

- Three EEGs with 60 farmers from different crops: coffee, cacao and citrus
- Three phases: normal climate variability, climate change conditions, adaptation to collective strategies .
- Understanding of farmers' perceptions of the adaptation strategies and their willingness to use microfinance as a mean to implement those strategies

Surveys

- Changes in weather
- Effects of CC
- Adaptation strategies
- Access to microfinance
- Perception about adaptation strategies through microfinance
- Household information

Interviews

- Semi-structured
- With three local leaders, and one member of the microfinance institution
- Understanding in agricultural practices, climate, effects of climate change in the agricultural systems and water resources management
- Exploring of access to microfinance, advantages compared to traditional financial services

5.1. Experimental Economic Games (EEGs)

EEG is a methodology that has been widely used to understand the perceptions of people in specific situations (Ostrom *et al.,* 1994; Cárdenas and Ostrom, 2004; Alpízar *et al.*, 2011; Moreno-Sánchez and Maldonado, 2010). They help explore changes in the behaviour of a person when faced with different scenarios and decisions to get the greatest possible benefit in any given situation. Thus, through EEGs specifically designed for this purpose one can learn about how farmers make decisions to invest through microfinance products in ecosystem-based adaptation strategies that may enable them to adapt to extreme weather events.

Since the communities involved in the MEbA Project use rainfed agriculture, the strategies assessed in the EEGs were those which focus on alleviating the threats that affect this type of agriculture, such as droughts, marked changes in rainfall patterns and wind storms. Therefore, from the 40 strategies proposed by Buenfil *et al.* (2013), the strategies selected for the game were aimed at: i) improving the efficiency of the use of rainwater through increased moisture, infiltration and water storage in soil; ii) improving the soil structure in order to reduce runoff, evaporation and increase nutrients; iii) reducing wind erosion; and, iv) increasing and diversifying income sources. The strategies assessed were the following:

1. Agroforestry system
2. Beekeeping
3. Crop diversification
4. Drip irrigation
5. Integrated Pest Management (IPM)
6. Natural shade
7. Organic farming
8. Reservoir for rainwater
9. Seed bank
10. Soil conditioning
11. Solar dehydrator

The EEG proposed in this thesis combines the methodology developed by Alpízar *et al.* (2011) and Escobar *et al.* (2013). The former explores the level of risk of coffee farmers in Costa Rica to face climate change and its implication on investing in adaptation strategies. The latter simulates the water use of high-mountain farmers of Boyacá region in Colombia under certain climatic conditions, for which the community must decide whether to adapt or not in cooperation with other farmers.

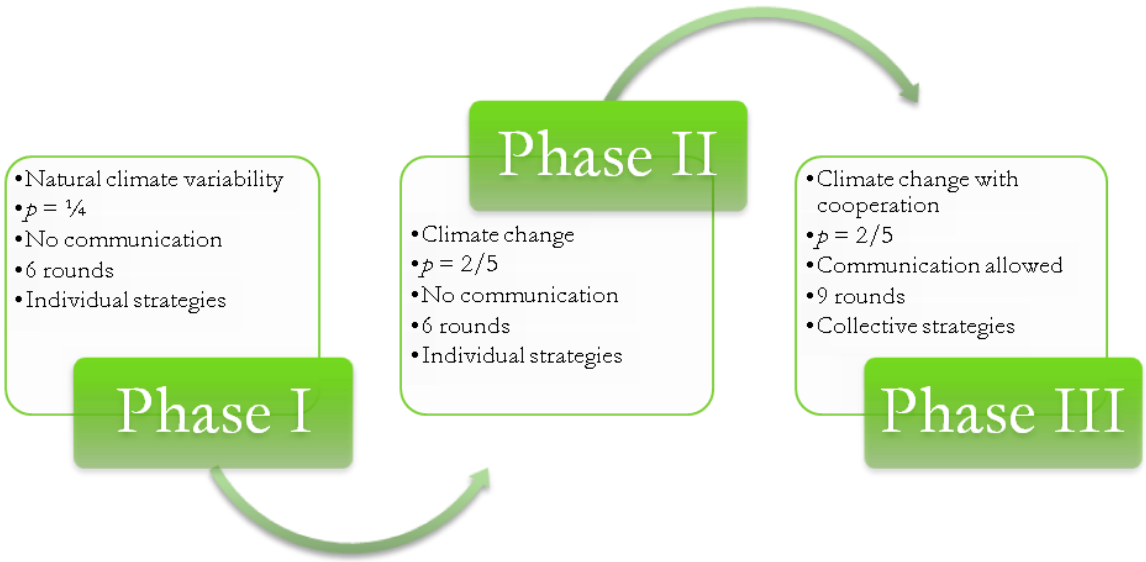
For the purposes of this thesis and to evaluate previously selected adaptation strategies, the game included the scenarios used in Alpízar *et al.* (2011) where the farmer had the choice to invest or not in climate change adaptation and his/her profits of the game depend on that decision. On the other hand, climate variability was modelled according to Escobar *et al.* (2013) which simulates natural variability at the beginning of the game and then introduces climate change by increasing the frequency of specific weather events consistent with the expected patterns of climate change. Unlike Escobar *et al.* that uses precipitation as a climatic variable, this game includes droughts since this variable also significantly affects rainfed agriculture.

In the game participants had the possibility of early adaptation to the effects of climate change. To do this, each player could invest in an adaptation strategy that would reduce the risk of losing some or all of their crops when heavy rains or droughts are present.

The game consisted of three phases. Phase I models the natural climate variability estimated by the Andean region according to Escobar *et al.* (2013), Phase III includes climate change by intensifying the frequency of weather events and Phase III introduces adaptation in groups. During the first two stages of the game, players had no communication with each other and their decisions were taken individually and privately. At this point, no player knew the decisions of the other players. In Phase III, there was the opportunity to communicate according to the instructions made by the moderator. Figure 5 presents the characteristics of this phase.

The first two phases consisted of six rounds and the last phase of nine rounds. Each round represented one harvest period (from soil preparation and planting to harvest) in which the players of each group had to decide whether to invest in an adaptation strategy defined at the beginning of the game. Each group had the possibility to adapt to a different strategy which had different costs and benefits, depending on its ability to tackle the impacts of climate change and its potential to generate income; characteristics that have already been estimated by Buenfil *et al.* (2013). In Phase III, participants had the possibility to invest in a group (i.e., work together) in a collective adaptation strategy. This phase was designed to evaluate the willingness of farmers to get associative microcredits as an option to invest in adaptation together; thus, Objective 3 of the thesis can be evaluated.

Figure 5. Diagram of the characteristics and sequence of the experimental economic game



The total gains of each player depended on their individual and collective decisions and the climate variability for each round/harvest. At the end of the game, each player received a prize corresponding to the total profits obtained throughout the game. The prizes awarded were tools used in agriculture and useful for their daily activities, such as hoes, rakes, shovels and machetes. The biggest prize was a pump back used to fumigate with organic pesticides which was awarded to the person with the highest profits.

5.1.1. The Theoretical Model of the Experimental Economic Game

The theoretical model proposed in this thesis simulates a payment function where the individual decision of investment and the climate variability define the profits obtained in each round, as presented in Equation 1:

$$\pi_{i,n} = f\left[I_{i,n}(0,1)\right], f\left[W_n(0,1,2)\right] \qquad (1)$$

where i = each participant (from 1 to 5 in each group), and

n = each round (from 1 to 12 in the first two phases of the EEG)

The first term of the equation represents the investment decision made by the participant where *0* means *"Not invest"* and *1* means *"Invest"*. The second term of the equation represents the weather corresponding to each round where *0* indicates *normal weather*, *1* represents *heavy rains* and *2* represents *droughts*.

Thus, the profits of each participant in each round are modelled by Equation 2:

$$\pi_{i,n} = \begin{cases} if\left(I_{i,n}=1\right) & and \quad W_n = 1{,}2 \quad then \quad \pi_{i,n} = P_{total} - Cost_s; \\ if\left(I_{i,n}=1\right) & and \quad W_n = 0, \quad then \quad \pi_{i,n} = P_{total} - Cost_s + Benefits_s; \\ if\left(I_{i,n}=0\right) & and \quad W_n = 1{,}2 \quad then \quad \pi_{i,n} = P_{total} - \beta P_{total}; \\ if\left(I_{i,n}=0\right) & and \quad W_n = 0 \quad then \quad \pi_{i,n} = P_{total} \end{cases} \tag{2}$$

This function includes all the possible profits that a participant could get with different weather states: normal weather or extreme weather (heavy rains or droughts). If there is normal weather and the participant decides not to invest, then his/her profits will be the average of profits he/she gets for a normal harvest: P_{total}. But in case of extreme weather, the participant will lose a great portion of his/her harvest, represented here by *β*.

When the participant decides to invest, regardless of the state of the weather for that round, the participant must pay the investment cost of the strategy *s* assigned for his/her group. In case of extreme weather, the player will receive the difference between P_{total} and the corresponding cost of the strategy. But in case of normal weather, the profits the participant gets include the economic benefits generated by the strategy, such as an increase in the productivity or the generation of alternative income.

It is important to clarify that the theoretical model assumes that the benefits of the strategies are perceived almost immediately, as the strategies were estimated to show results up to one year (Buenfil *et al.*, 2013). In addition, a limitation of this model is that farmers may not be motivated only by economic issues but also other factors that may not be explicitly captured by this experimental game.

As the players want to maximize their profits in each round, they must face the risk of losing a great portion of their harvest when they decide not to invest. Likewise, they lose money when they decide to invest and the weather is normal because in that case they have to pay an unnecessary cost: the investment cost of the strategy. Thus, the highest profits are reached when the participant invests and the weather is extreme or when the participant does not invest but the weather is normal.

In Phase III of the EEG, the participants must decide in a group whether to invest in a new adaptation strategy. In this case, the profits of each player will depend on the individual and group decision as presented in Equation 3:

$$\pi_{i,j} = f\left\lfloor I_{i,j}(0,1)\right\rfloor, f\left[W_n(0,1,2)\right], f\left\lfloor I_j(0,1)\right\rfloor \qquad (3)$$

where j = each group (from 1 to 4)

The strategy is implemented if three or more players of the same group decide to invest, otherwise the strategy is not implemented. Therefore, the investment decision of the group is defined by Equation 4:

$$\left\{ if \sum_{i=1}^{i=5} I_i \geq 3, \quad then \quad I_j = 1; \quad otherwise \quad I_j = 0 \right\} \quad (4)$$

Once the group decision has been taken, the individual profits can be calculated using Equation 2 and taking into account that now the individual decision is the same as the one taken by the group.

5.1.2. Parameterization of the theoretical model

Defining the parameters used in the profits function it is easy to calculate all the possible profits that a participant can get in one round of the game. According to the MFI Crezcamos (Osorio, interview), the average profit that a farmer obtained from each harvest when there is natural climate variability, in other words normal weather, is USD $1,250. Therefore, P_{total} = 1,250. However, according to Alpízar *et al.* (2011) when there are extreme weather events, farmers can lose 90% of their total harvest. In this case β=0.9. Comparing to the information given by Jaime Osorio, Director of Methodologies and Products of the Microfinance Institution Crezcamos during an interview, farmers state that they could lose anywhere between 70 to 100 percent of the harvest, which means that the parameter β=0.9 is accurate.

Other parameters that must be defined to estimate the possible profits are the costs and benefits of each adaptation strategy. Buenfil *et al.* (2013) estimated the different implementation costs including the costs of labour, training and materials. These costs are the total investment that a farmer must make to implement any given adaptation option. Since these costs cannot be paid in one payment, a microfinance service, such as microcredit is offered to the farmers. In this sense, the investment cost for each strategy, used in the EEG, corresponds to the payment that one farmer must make in one harvest period.

This payment was calculated with Equation 5:

$$Cost_s = \frac{MEbACost_s}{t} * b \qquad (5)$$

where *MEbA Cost* = is the total implementation cost estimated by Buenfil *et al.* (2013)

t = average time in which microcredits are awarded

b = number of months that one growing season lasts

In Phase III, the participants can invest in groups in a new adaptation strategy. In this case, the total cost of implementation is shared among the five players of each group. Therefore, the individual cost that each individual must pay when the group decides to invest, is defined by Equation 6:

$$Cost_{group\_strategy} = \frac{Cost_s}{i} \qquad (6)$$

According to the MFI Crezcamos (Osorio, interview), the average period of microcredits in the Santander region is 20 months. They also stated that most of the crops have harvests of about six months. Taking into account that each group has five players, both costs can be calculated. The resulting investment costs for each strategy are presented in Table 4.

Table 4. Investment cost of each adaptation strategy (USD)

Individual strategies	Investment Cost	Group strategies	Investment Cost
Beekeeping	800	Agroforestry system	400
Crop diversification	750	Natural shade	400
Drip irrigation	1,100	Organic farming	1,050
Integrated Pest Management	900	Reservoir for rainwater	550
Soil conditioning	950	Seed bank	700
Solar dehydrator	450		

As part of the limitations of the theoretical model is that the benefits offered by these adaptation strategies were estimated only in economic values. Some of the benefits include an increase of productivity, reduction in inputs and materials or introducing alternative sources of income. All these benefits were evaluated by Buenfil *et al.* (2013) as the potential to generate income by each strategy. They assigned a grade from 1 to 3 according to the potential that each strategy has. This grade was used to calculate the benefits, as presented in Equation 7:

$$B_s = \frac{a_s}{10} P_{total} \qquad (7)$$

where a_s = Potential to generate income

The resulting benefits are presented in Table 5:

Table 5. Economic benefits of each adaptation strategy

	Economic benefits of the strategy (USD)	Potential to generate income
Agroforestry system	250	2
Beekeeping	375	3
Crop diversification	375	3
Drip irrigation	400	3.2
Integrated Pest Management	125	1
Natural shade	250	2
Organic farming	375	3
Reservoir for rainwater	250	2
Seed bank	250	2
Soil conditioning	125	1
Solar dehydrator	250	2

Having all the parameters estimated and using Equation 2, the possible profits that a participant could get in one round according to their decisions and the weather, are presented in Table 6:

Table 6. Possible profits that a participant could get in one round (USD)

	Invest		**Not invest**	
	Extreme weather	Normal weather	Extreme weather	Normal weather
Agroforestry system	850	1,100	125	1,250
Beekeeping	450	825	125	1,250
Crop diversification	500	875	125	1,250
Drip irrigation	150	550	125	1,250
Integrated Pest Management	350	475	125	1,250
Natural shade	850	1,100	125	1,250
Organic farming	200	575	125	1,250
Reservoir for rainwater	700	950	125	1,250
Seed bank	550	800	125	1,250
Soil conditioning	300	425	125	1,250
Solar dehydrator	800	1,050	125	1,250

5.1.3. Structure of the EEG

5.1.3.1. Phase I: Natural climate variability

As the decision of investing and taking a microcredit or another microfinance product is taken individually, the strategies evaluated in this phase were those identified by Buenfil *et al.* (2013) to be implemented for one person or one household. The adaptation option for each farmer depended on the crop they grow and the group where they were playing. Thus, the strategies were distributed as presented in Table 77:

Table 7. Strategies assessed in Phases I and II of the EEG

	Coffee	Citrus	Cocoa
Group 1	Solar dehydrator	Beekeeping	Beekeeping
Group 2	Beekeeping	Integrated Pest Management	Integrated Pest Management
Group 3	Integrated Pest Management	Drip irrigation	Drip irrigation
Group 4	Crop diversification	Soil conditioning	Crop diversification

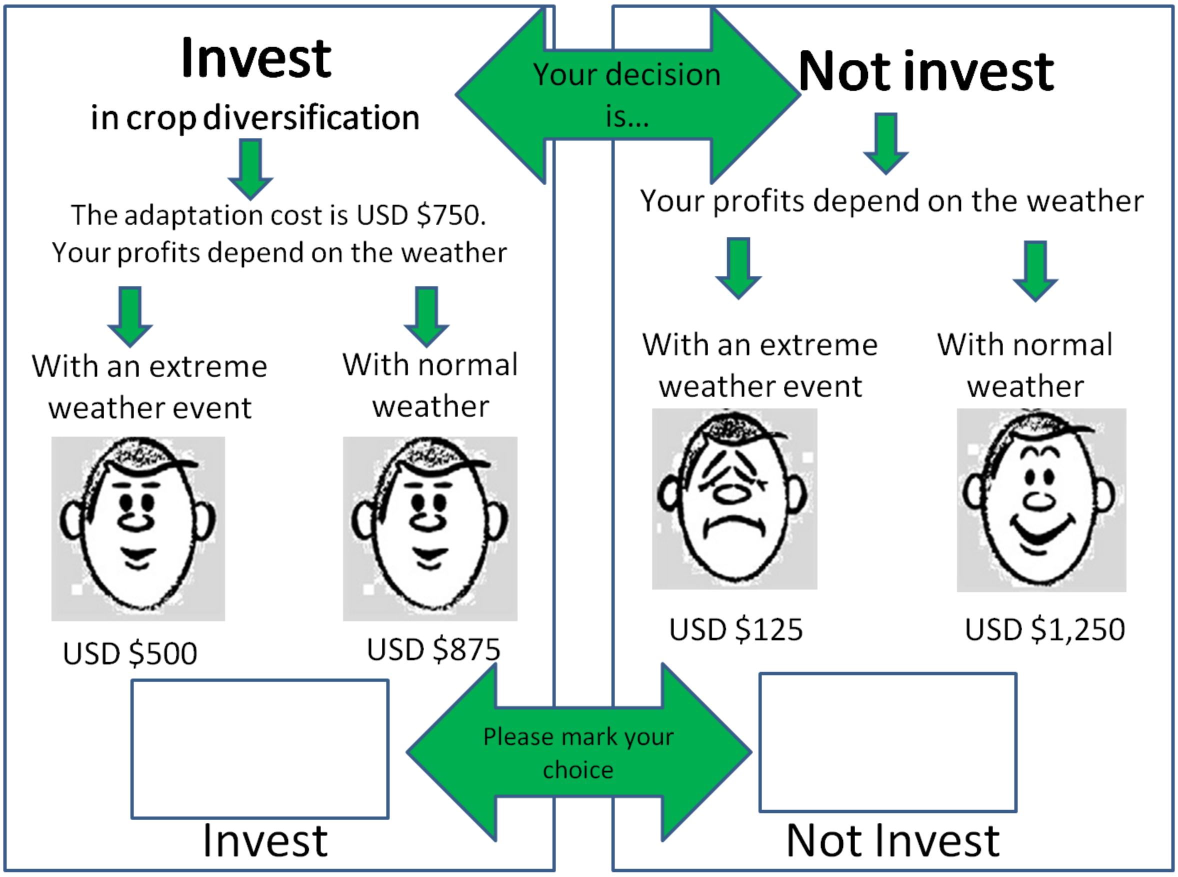
At the beginning of this phase, the facilitator of each group described the corresponding adaptation strategy according to the definition proposed by Buenfil *et al.* (2013), clarifying the economic benefits and costs of investing in that strategy.

Besides, this phase aimed at modelling the natural changes in temperature and rainfall that farmers face each year of harvest, in other words, this phase is the baseline without introducing climate change conditions. To represent variations in weather, this EEG followed the climate modelling by Escobar *et al.* (2013) where levels of precipitation were represented by yellow balls in a black bag and normal precipitation with green balls. Escobar *et al.* (2013) estimated that the probability of having low precipitation (negative climate variability) was p=1/4.

In this thesis, the negative climate variability was defined as having heavy rains or drought during the harvest period. Thereby, the weather was represented by eight balls in a black bag: six green balls (normal level of precipitation and no droughts), one blue ball (heavy rains) and one red ball (droughts). Hereby, the probability of having bad or extreme weather was p=1/4. Once the players have decided whether invest in adaptation, the facilitator drew one ball from the black bag to determine the weather for that harvest/round.

The benefits of each round depended on the decision taken by the farmer and the weather selected for that period. Each player started the round with US $1,250 which according to the MFI Crezcamos (Osorio, interview) is the average profit a farmer gets for a harvest. Thus, if the facilitator drew a green ball that assumes normal climate variability and the player decided not to adapt, earnings for that round would be US $1,250. But in the case of heavy rains or drought, the benefits were greater when the player decided to adapt, as presented in Table 6, otherwise the participants' profits would be only US $125 representing 90% of losses, as has been estimated by Alpizar *et al.* (2011).

Figure 6. Example of the Decision sheet for EEGs



Source: Modified from Alpízar *et al.* (2011)

For each round, participants had one *Decision sheet* where they could mark their decision, as shown on Figure 6. These sheets changed according to the group and the crop corresponding to each player. All the *Decision sheets* used in the EEGs are presented in Appendix 1. A total of six rounds were played in this phase.

5.1.3.2. Phase II: Climate Change

At this stage, farmers experienced the effects of climate change represented in the game by rains and periods of droughts. Escobar *et al.* (2013) introduced climate change by increasing the probability of having negative climate variability, stated in p=2/5. To simulate climate change in this game, one blue and one red ball were added to the black bag, representing the higher frequency of heavy rains and droughts. In each round the facilitator randomly selected a ball to represent the weather after the players had made their decisions of investment. A total of six rounds were played at this stage of the game.

5.1.3.3. Phase III: Climate change with cooperation

In this phase, players had the possibility to adapt anticipatively to the effects of climate change but in a collective way. At the beginning, the facilitator introduced a new adaptation strategy that might be implemented by a few farmers and shared its cost. These strategies were defined by Buenfil *et al.* (2013) as collective strategies since they provide benefits for more than one household/farm or because they can be implemented in a shared land. The strategies introduced in this phase are presented in Table 8.

Table 8. Strategies assessed in Phase III of the EEG

	Coffee	**Citrus**	**Cocoa**
Group 1	Natural shade	Agroforestry system	Natural shade
Group 2	Agroforestry system	Seed bank	Organic farming
Group 3	Reservoirs for rainwater	Reservoirs for rainwater	Reservoirs for rainwater
Group 4	Organic farming	Organic farming	Agroforestry system

After the facilitator explained the collective adaptation strategy, the five players of each group had the possibility of dialogue for two minutes to decide collectively whether to invest in adaptation. Then, each player marked their own decision in the *Decision sheet* which could represent agreement or disagreement with what was decided in the group. The facilitator collected all five *Decision sheets* and announced the group decision. The strategy was implemented only if three or more players voted to invest. This final group decision was adopted for three rounds, which meant that during three harvests all players, regardless of their individual decision, had to pay the adaptation cost in case the group decision was to invest or face the risk of losing their harvest in case of no investment.

Every three rounds, players could communicate to decide collectively. A total of nine rounds were played in this phase with three rounds of communication.

5.1.4. Statistical analysis of the data

The data gather from the EEGs is analyzed through McNemar test. This method of analysis is used to compare paired responses from the same individual at different moments. It assesses the significance of the difference in both responses, which demonstrates that the changes are due to the treatment of the experiment instead of being just random responses (Walpole *et al.*, 1993). Thus, changes in farmers' responses from one phase to another of the game can be analyzed to know whether those changes correspond to the increased of risk of extreme weather events.

McNemar test is used in 2x2 contingency tables as Figure 7 where A represents the first response and *B* the second response. Note that the response must have only two options (1 or 0), for the case of the EEGs the response is whether 'adapt' or 'do not adapt'.

Figure 7. McNemars' contingency table

General Structure		B		
		1	0	Totals
A	1	a	b	a+b
	0	c	d	c+d
	Totals	a+c	b+d	N=a+b+c+d
p_A = (a+b)/N p_B = (a+c)/N				

The *T* statistic used in the decision rule is calculated by Equation 8 (Walpole *et al.*, 1993). All the calculations in this thesis were made through the website http://www.graphpad.com/quickcalcs/mcNemar2/.

$$T_1 = \frac{(|B-C|-1)^2}{B+C} \qquad (8)$$

5.2. Description of the adaptation strategies

Buenfil *et al.* (2013) has proposed 40 strategies that might help small farmers from the Andean region to adapt to climate change or mitigate its impacts on agriculture. From these strategies, the MFI Crezcamos has selected 11 to be assessed through this thesis. The definition of these strategies is presented according to Buenfil *et al.* (2013):

5.2.1. Agroforestry system

This adaptation strategy promotes the production and use of multiple layers of an ecosystem by planting different species of timber and fruit trees as shrubs, herbs and tubers. Large trees help create shade that protect crops from extreme heat, heavy rains or strong winds. Livestock feeds on shrubs and small plants, and tubers and herbs are used for household consumption and for sale. This process makes the soil more fertile and productive. For instance, in Peru it was found that this practice is five times more productive in coffee cultivation (Brack, 2004). In addition, the agroforestry system reduces the amount of inputs needed through interactions between different species of trees and shrubs.

5.2.2. Beekeeping

This measure consists of the rearing of bees to take advantage of the products obtained from them as honey, wax, jelly, propolis, pollen and venom. This measure increases the productivity of neighboring land through pollination and generates a new source of income for farmers to help them in case of loss or damage to crops. The income received from beekeeping can generate a return of up to 38%, as was estimated by Magaña and Leyva (2011) in Mexico. Indeed, Kasina *et al.* (2009) estimated that beekeeping contributes almost 40% of the total annual income of small farmers who use this practice in their farms.

5.2.3. Crop diversification

This measure consists in planting various crops on the same farm where their production is alternated. Diversification includes multiple associations, fruit trees, vegetables and forest trees. This diversity reduces the number of insects that damage crops, it also controls pests through biological control where antagonist species are planted. This practice allows a better use of spaces, recycles nutrients, creates microclimates and properly manages water resources. It also prevents losing the entire crop for extreme climates because the risk of loss is spread by having several crops. Crop diversification is more resilient than the monoculture since it tackles sudden changes in temperature, change in rainfall patterns and extreme heat. Altieri (2002) states that the diversification of crops increases the productivity of soils and harvests from 20% to 60%.

5.2.4. Drip irrigation

Drip irrigation is an irrigation system that allows optimal use of water and fertilizers for crops. This system uses water droppers sent directly to the roots of crops. Thus, evaporation of water is avoided and promotes savings of up to 70% compared to conventional irrigation systems, which are reflected in a 35% increase of in farmers' income (FINTRAC, 2001). The frequency with which inputs are supplied is high ensuring the required amount of water and fertilizer. This measure reduces risk by changes in rainfall patterns and drought and can also grow even in times of low water availability.

5.2.5. Integrated Pest management

Through mechanical control, biological control and crop rotation, this measure helps to control pests and diseases. It is very useful in places where there are large fluctuations in temperature and heavy rainfall. This measure replaces the use of pesticides and herbicides by organic products, benefiting human health and the environment. This practice also reduces the use of inputs when pests reproduce and spread rapidly, reducing the number of pesticide applications and increasing farmers' income (Ortiz and Pradel, 2009).

5.2.6. Natural shade

This adaptation strategy creates shade by planting native and perennial trees to protect animals, crops and other species from excessive sun exposure. As first step, trees that help improve soil structure, recycle nutrients and create organic matter are sown, which reduces the use of fertilizers (Altieri, 1999). Then, those trees whose branches provide natural shade are planted to help keep moisture in the soil, favoring crops in dry seasons and protecting them from hail and heavy rain. The diversity of trees planted can also generate new revenue for the production of fruit and wood. It is estimated that a coffee crop under shade can produce up to 3,500 kg/ha per year, in Colombia (Farfán, 2007).

5.2.7. Organic farming

This practice is useful in soils damaged by high use of agricultural activity. It entails the combination of agricultural practices to increase soil resilience to climate variability. It introduces some traditional practices such as terraces and platforms that preserve biodiversity and achieve sustainable production. This practice is aimed at balancing the flow of energy and nutrients in different soil depths through the interaction of polycultures, animals and organic fertilizers. Thus, the impacts on the environment are minimized, as it helps to fertilize the soil and conserve water by using mulch. All this process creates a biological and ecological balance of the ecosystem that makes it easier to face heavy rains and extreme heat. This measure helps to control erosion and pests, to diversify income and higher productivity in the long run.

5.2.8. Reservoirs for rainwater

The rainwater reservoirs are small reservoirs to store water from rainfall and runoff from other farms. It is a strategy that can be implemented individually or in group as it not only receives water from various fields but can also be used by several farmers for irrigation or as ponds for livestock and other animals. They diminish the impact of drought and uses the excess water in times of heavy rains. The reservoirs can generate microclimates if combined with revegetation actions. A 500m^3 water reservoir of can deliver water to 80 animals or provide irrigation water for growing vegetables of 2,500 m^3 (SAGARPA, 2009).

5.2.9. Seed bank

This adaptation strategy seeks to store in a safe and dry place seeds with the best features of product quality and more resistant to large changes in climate. By retaining the best seeds, genetic biodiversity, sustainability and food security of small farmers' autonomy are promoted. This is a collective strategy because farmers can borrow seeds before planting and then after harvesting they return the seeds with some interest. Also, you can create a business of organic seeds for sale.

With this measure, crops are more resistant to frost and extreme heat. It was estimated that the use of several varieties of seeds to face plague contributed, in 1997, in USD 15 billion to the global economy (Couch *et al.*, 2013).

5.2.10. Soil conditioning

This adaptation strategy is to increase soil organic matter, improve nutrient management and soil erosion control through crop rotation and use of organic fertilizers. To do this, it is necessary to make a preliminary soil study that shows what should be the tillage and fertilizing practices to improve soil productivity. This process improves soil quality and productivity, in turn-reducing production costs. This measure also improves moisture and soil infiltration, decreasing impacts in times of drought, extreme heat and heavy rains.

5.2.11. Solar dehydrator

Using the heat from the sun and a drying system through air circulation, this measure helps reduce the amount of water contained in fruits, seeds, vegetables and meat. Thus, the nutrients in the food are retained and the growth of microorganisms that decompose is avoided. Therefore, marketing foods can be processed more efficiently and their nutritional component is favoured. Since their sources are the sun and the wind, this dehydrator can be used at any time of year, so it is quite an appropriate strategy for drying coffee beans. Moreover, as the sola dehydrator does not require gasoline or electricity for operation, costs are zero and the emission of greenhouse gases is prevented.

5.3. Surveys

One survey was carried out with farmers of Rionegro who participated in the economic games for a total of 60 surveys. Through this survey one can identify the indebtedness of farmers, their receptivity to financial products, climate events that affect their crops and solutions that could be of greater help to reduce their vulnerability and increase their adaptive capacity. The surveys are also a tool to identify strategies that might be more useful and accessible for farmers. The design of the survey with participants of the EEGs is presented in Appendix 2.

5.4. Interviews

Four interviews were conducted: one with an employee of the MFI Crezcamos, Jaime Osorio, and three interviews with the farmer leader of each crop as members of farmers' associations. Interviews with farmers were semi-structured, with open and closed questions that favour understanding of impacts of climate change in the agriculture of the study area, agricultural practices used by farmers, management of water resources and the annual variability of the climate. The interview with the member of the MFI was aimed at finding out the intention of the MFI to offer microfinance products to farmers and to explore the importance of the adaptation strategies in the improvement of quality of life of farmers. The design of the two interviews is presented in Appendices 3 and 4.

6. Results

6.1. Experimental Economic Games

The EEGs were conducted in one Colombian community in the Santander Region, named Rionegro; with small farmers of coffee, citrus and cocoa. Three games were played with farmers from three different crops. Each game was conducted with a maximum of 20 participants, who played in groups of 5 with the help of facilitators. Therefore, a total of 60 farmers played in the EEGs and were later surveyed. Through the games, eleven adaptation strategies were assessed: six individual and five group strategies. The individual strategies were assessed in Phases I and II. The former is the baseline and corresponds to natural climate variability and the latter introduces climate change. The strategies in group were included in Phase III were the cooperation of the participants is evaluated.

In total, three groups played with the strategies of agroforestry system, beekeeping, Integrated Pest Management, organic farming and reservoir for rainwater. Two groups of farmers played with crop diversification, drip irrigation and natural shade; and one group with seed bank, soil conditioning and solar dehydrator (Table 9). The number of groups for each strategy was agreed with the team work of MFI Crezcamos.

Table 9. Total number of farmers that played with each adaptation strategy in the EEGs

	Crop			
Adaptation strategies	**Coffee**	**Citrus**	**Cocoa**	**Total**
Agroforestry system	5	5	5	15
Beekeeping	5	5	5	15
Crop diversification	5		5	10
Drip irrigation		5	5	10
Integrated Pest Management	5	5	5	15
Natural shade	5		5	10
Organic farming	5	5	5	15
Reservoir for rainwater	5	5	5	15
Seed bank		5		5
Soil conditioning		5		5
Solar dehydrator	5			5

6.1.1. Investment decisions in adaptation to climate change

One of the strengths of the EEGs is that it allows one to assess the decisions of farmers to invest in adaptation to climate change under simulated conditions. These decisions can be assessed according to farmers' behaviour throughout the game and the responses they provided in the survey.

To evaluate the adaptation decisions it is important to analyse factors that influence them, including: i) risk to lose the harvest as a consequence of effects of climate change, ii) characteristics of the adaptation strategies such as their benefits, costs and their potential to tackle the impacts of climate change; iii) the possibility to take decisions individually or as a group; and, iv) farmers' borrowing capacity and access to microfinance services to be able to invest in adaptation. All these factors are analyzed in this chapter.

6.1.1.1. Effects of different climate variability on crop losses

The risk of losing the harvest as a consequence of the impacts of climate change is represented in the EEGs as the probability of having extreme weather events that might damage a great portion of the harvest, such as droughts and heavy rains. In Phase I, the_theoretical model indicates that participants had the possibility to invest in adaptation given 25% of probability of having extreme weather. In practice during the games, these extreme events occurred with a probability of 22% in all rounds played in Phase I. In Phases II and III, this probability was set at 40% but in practice droughts and heavy rains occurred with 46 and 42 percent probability, respectively.

Analyzing the data gathered in all EEGs, farmers preferred investing in adaptation in all three phases of the game (Table 10). However, the decision to adapt was more evident in those stages (Phases II and III) where climate variability was greater and climate change was experienced. For instance, 63 and 79 percent of the farmers decided to adapt in Phases II and III respectively, while 54% adapted when climate variability was lower.

Table 10. Investment decisions with different risk of experience climate change in Phases I, II and III

	Phase I Normal climate variability *p = 0.25*		Phase II Climate change *p = 0.4*		Phase III Climate change with cooperation *p = 0.4*	
	Number of Observations	%	Number of Observations	%	Number of Observations	%
Do not adapt	165	45.83	133	36.94	113	20.93
Adapts	195	54.17	227	63.06	427	79.07
Total of Observations	360		360		540	

Those results also suggest that farmers are risk averse when it comes to tackling climate change, which is one of the hypotheses of this thesis. They prefer adapting when the likelihood of heavy rains and droughts increases, so as not to lose their crops. To confirm statistically that hypothesis, the McNemar test is used. This method of analysis is used to prove if the changes in farmers' behaviour (more preference to adapt when there is climate change) are due to an increase of probability of having droughts and heavy rains instead of being just random responses (Walpole *et al.*, 1993). To apply the McNemar test it is necessary to compare the responses of each farmer in each round given both probabilities p=0.25 and p=0.4. Table 11 presents the number of responses by farmers that changed from Phase I to Phase II. For instance, a total of 42 responses changed in Phase I from adaptation to not adapt in Phase II. Likewise, 74 responses that chose not to adapt when there was normal climate variability and then decided to adapt when climate change was experienced.

Table 11. Changes in responses from Phase I to Phase II

		Climate change ***p = 0.4***		
		Adapt	Do not adapt	**Total**
Normal climate variability ***p = 0.25***	Adapt	a=153	b=42	195
	Do not adapt	c=74	d=91	165
	Total	227	133	**360**

With this information, the hypothesis can be tested as follows:

$H_0: b = c$
$H_1: b \neq c$
$\alpha = 0.5$
McNemar's chi square $X^2 = 8.28$[3]
$df = 1$
Reject H_0 if $X^2 > 3.84$

According to the results, there is a significant difference ($X^2 = 8.28$, $p<0.005$) in the farmers' responses that indicates that they prefer adapting when the probability of having an extreme weather event is higher. However, these preferences might change with the farmers of different crops. The next section analyzes those changes.

6.1.1.2. Farmers' decisions from different crops according to climate variability

The decision to invest in adaptation to climate change not only differs if the person is risk averse or risk taker, but also depends on the type of crop he/she grows. Every crop has its own requirements in weather, exposure to sun, soil conditioning and water and irrigation needs in order to grow properly. These requirements change the priorities and preferences of farmers, which are presented in Table 12.

When analyzing the data by crop, the trend to prefer adaptation in all three phases of the game is not observed. For instance, coffee farmers chose not to invest in adaptation in Phase I, and citrus farmers chose not to do so in Phase II. In all three crops, the third stage scored the highest percentages of adaptation decisions. Still, except for citrus, coffee and cocoa crops had higher adaptation decisions with the increasing likelihood of climate change.

[3] McNemar's chi square was calculated through the website http://www.graphpad.com/quickcalcs/mcNemar2/

Table 12. Changes in adaptation decisions of farmers according to their crops during Phases I, II and III

Coffee

	Normal climate variability $p = 0.25$		Climate change $p = 0.4$		Climate change with cooperation $p = 0.4$	
	Number of observations	%	Number of observations	%	Number of observations	%
Do not adapt	65	54.17	39	32.50	17	9.44
Adapts	55	45.83	81	67.50	163	90.56
Total of Observations	120		120		180	

Cocoa

	Normal climate variability $p = 0.25$		Climate change $p = 0.4$		Climate change with cooperation $p = 0.4$	
	Number of observations	%	Number of observations	%	Number of observations	%
Do not adapt	49	40.83	33	27.50	45	25.00
Adapts	71	59.17	87	72.50	135	75.00
Total of Observations	120		120		180	

Citrus

	Normal climate variability $p = 0.25$		Climate change $p = 0.4$		Climate change with cooperation $p = 0.4$	
	Number of observations	%	Number of observations	%	Number of observations	%
Do not adapt	51	42.50	61	50.83	51	28.33
Adapts	69	57.50	59	49.17	129	71.67
Total of Observations	120		120		180	

Although coffee farmers preferred not adapting when there is normal climate variability, they had the greatest difference in the responses observed in Phase II, since more than 21% changed from no adaptation to adaptation. Less variation in responses is observed in citrus cultivation, where 8.33% changed from adapt to not adapt in Phase II. One might think that the decision not to adapt depends on the adaptation strategies proposed for each group, but Phases I and II were developed for each group with the same strategy, so the only change was in the increased climate variability. An in-depth analysis of how strategies influence adaptation decisions will be made in the next section.

It is also observed that cocoa farmers were those who were most likely to choose adaptation; 23% over the likelihood of adaptation by citrus farmers. However, the responses of citrus farmers at the climate change stage were evenly distributed since there was only a 1.6% difference between response for no adaptation and adaptation. This is why it is important to assess whether differences in the decisions between Phases I and II are statistically significant. To do this, the McNemar test was again performed and results are presented in Table 13.

Table 13. McNemar test for each crop

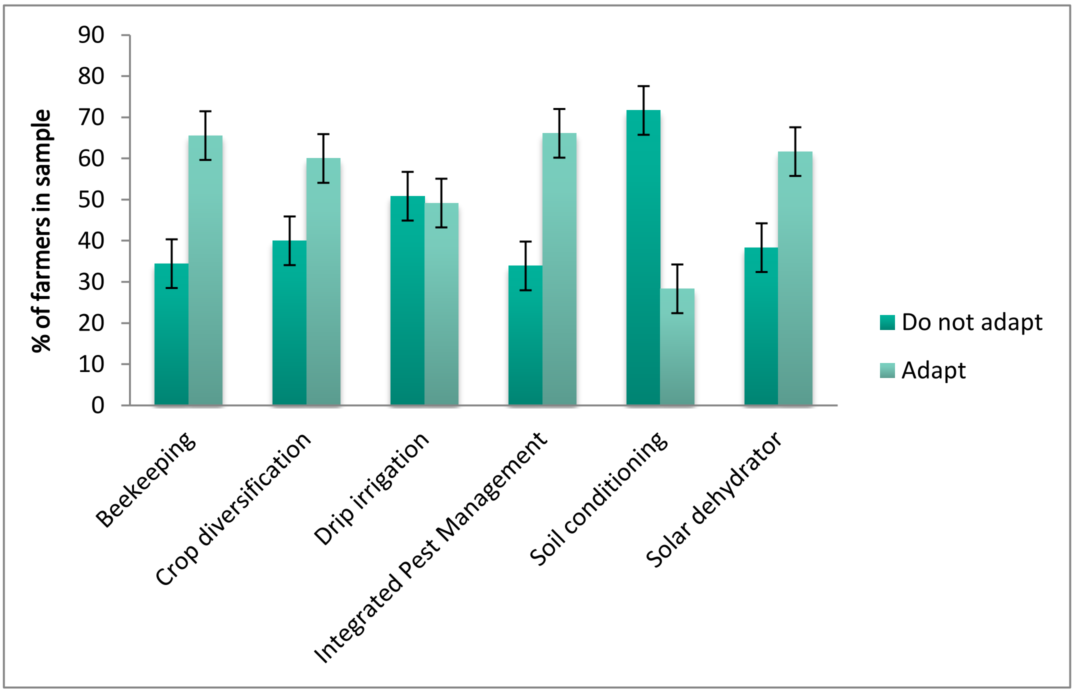
	Coffee	Cocoa	Citrus
McNemar X^2	13.59	7.03	2.13
p-value	0.0002	0.008	0.14

The McNemar test proves that there is a significant change in the responses of coffee farmers when they were facing climate change in the EEG. This difference is the most significant among the three crops. But still, cocoa farmers' responses also changed significantly demonstrating that they prefer adaptation when the risk of losing the harvest is higher. By contrast, there is no significant difference in the responses of citrus farmers, which may indicate that they are risk takers, or simply that the proposed strategies for this crop do not sufficiently mitigate the impacts of climate change, and therefore it is not worth investing in them. To explore the reasons that motivated citrus farmers to invest in adaptation in times of climate change, it is important to analyze adaptation decisions according to the strategies assigned to each crop.

6.1.2. Adaptation decisions according to the strategy

In this section the decisions taken by the farmers of the three crops of investing in individual adaptation strategies (those that can be implemented by a farmer or household) will be explored. Figure 8 presents the average percentage of the likelihood of adaptations for each strategy during Phases I and II. It is observed that farmers decided to invest in adaptation in almost all the strategies rather than not adapting. However, strategies such as drip irrigation and soil conditioning show a different behaviour. For instance, the difference on no adaptations in drip irrigation was only 1.7% over the farmers that decided to invest in this option. On the other hand, farmers did not want to invest in soil conditioning, as more than 70% of farmers opted for no adaptation.

Figure 8. Average percentage of the likelihood of adaptations in individual strategies during Phases I and II



The lack of interest in investment in drip irrigation and soil conditioning suggests that farmers take the cost into account. Both strategies have the highest prices (Table 4). To test that hypothesis, the Pearson Product Moment Correlation Coefficient was calculated: $r = -0.53$. This value for the Pearson Coefficient indicates that there is a substantial negative relationship between the cost of the strategy and the percentage of its likely use in adaptation; which means that with increasing cost, farmers choose the adaptation strategy at a lower level.

Now, knowing that farmers adapt more with increasing climate variability (according to the results of Table 13), one might think that the cost of investment becomes more important when there is climate change. Using The Pearson Coefficient to analyze the decisions taken during the two phases, one finds a trivial positive relationship (r = 0.08) for the normal climate variability phase and a substantial negative relationship (r = -0.63) for the climate change phase. This confirms that since farmers tend to adapt more when there is climate change, they take into account even more the cost of investment to make their decisions.

The previous analysis focuses on the general decisions without exploring the decisions taken in each adaptation strategy. Table 14 presents the changes in farmer' responses between the two phases in all individual strategies and their statistical significance.

Unlike drip irrigation and soil conditioning, the responses of farmers in all the other strategies increased under the conditions of climate change to the point where more than 70% of farmers preferred investing in adaptation strategies. This increase was significant in all strategies except for Integrated Pest Management (IPM) (McNemar X^2 = 1.44, p> 0.1), where several farmers (62%) chose to invest in this strategy even when the likelihood of experiencing bad weather was low. Therefore, in the case of IPM the change in responses between the two phases was not significant.

The preference for IPM indicates that regardless the weather, this is a necessary practice to protect the crop at any time from planting to harvest. In addition, some climate change events such as heavy rains may favour the rapid production and proliferation of pests on crops (Ortiz and Pradel, 2009).

Another adaptation strategy in which many farmers invested in both stages of the game is beekeeping. This measure, which can be implemented in any type of weather, was preferred by farmers perhaps for its potential to generate alternative income from the sale of honey and propolis. In addition, this strategy provides ecosystem services such as pollination and increased biodiversity. Although there was greater preference for this strategy in the stage of climate change, the difference was only moderately significant (McNemar X^2=3.11, p<0.1). These results are a consequence of the benefits of beekeeping. In times when climatic events affect the crop, farmers think they could use beekeeping as an alternative source of income to offset the loss of the harvest, and in times of good weather this practice would increase farmers' income.

The adaptation strategy that showed the greatest significance in changing farmers' responses was crop diversification (McNemar X^2 = 8.45, p <0.01). This behaviour suggests that the strategy is essential to adapt to climate change as it diversifies the risk of loss by growing several crops at the same time. Thereby, in case of unfavourable weather event the farmer may lose some, but not the entire crop.

Using solar dehydrators was an adaptation strategy evaluated only with coffee farmers because of the relevance on this crop, as it is necessary to dry the coffee beans before they are processed; which does not occur in the case of citrus and cocoa. Although coffee farmers of the study area use different methods of dehydration, none uses solar dehydrators (Santos, interview). There is significant preference for this kind of dehydrators (McNemar X^2 = 4.92, p <0.05), when climate change is experienced, because they are useful even in times of heavy rain as they do not require much sun exposure and also use air currents for drying the crop.

Table 14. Preferences of farmers according to the strategy

Beekeeping

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Observations	36	54	90	26	64*	90
%	40	60		28.89	71.11	

Crop diversification

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Observatons	31	29	60	17	43***	60
%	51.67	48.33		28.33	71.67	

Drip irrigation

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Observations	29	31	60	32	28 n.s.	60
%	48.33	51.67		53.33	46.67	

Integrated Pest Management

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Observations	34	56	90	27	63 n.s.	90
%	37.78	62.22		30	70	

Soil conditioning

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Observations	19	11	30	24	6 n.s.	30
%	63.33	36.67		80	20	

Solar dehydrator

	Normal climate variability $p = 0.25$			Climate change $p = 0.4$		
	Do not adapt	Adapts	Total Observations	Do not adapt	Adapts	Total Observations
Number of Obseervations	16	14	30	7	23**	30
%	53.33	46.67		23.33	76.67	

*** significant at 99%, ** significant at 95%, * significant at 90%, n.s. not significant

Drip irrigation and soil conditioning were strategies in which farmers reduced their investment when they were facing climate change (5% less investment in drip irrigation and 16.7% less in soil conditioning). Although farmers decided mostly not to invest, this reduction is not significant in either of the two strategies (drip irrigation: McNemar X^2=0.19, p>0.1; soil conditioning: McNemar X^2=1.45, p>0.1), which indicates that those changes in the decision may be due to other reasons than weather such as the investment cost as was demonstrated before.

Farmers had limited interest in investing in soil conditioning in both stages of the game; and this preference was even more evident under climate change with 80% of the responses (Table 14). It is important to highlight that this strategy was assessed only with citrus farmers who, according to their decisions, could suggest that this strategy is not appropriate for their crop. This behaviour of citrus farmers explains why the changes in their decisions from Phase I to Phase II were not significant, as presented in Table 13.

Another reason to explain these results could be the highest implementation cost of soil conditioning and its low potential to generate higher income -only 10%- (Tables 4 and 5), which offers a low motivation for investment. The main benefit of this strategy is the high productivity obtained once the soil has been completely conditioned i.e. its productivity significantly increased.

A similar situation occurs with drip irrigation since it had the highest implementation cost of all individual strategies assessed in the game (USD 1,100 per farmer). This could be the reason why farmers did not want to invest significantly in this strategy. Despite having a high implementation cost, drip irrigation has the highest potential to generate income among all the adaptation strategies (Table 5). In this sense, the high cost is reflected in an increase in revenue due to the reduction in the consumption of irrigation needed.

6.1.3. Adaptation strategies most appropriate to mitigate climate change effects according to the crop

This section addresses the Objective 1 of this thesis which seeks to understand which adaptation strategies are the most appropriate for each crop. The preceding section helped understand how farmers behave when they have the opportunity to invest in different adaptation options and to know their preferences regardless the crop they grow. This new section analyzes preferred adaptation strategies by crop.

6.1.3.1. Coffee

Among the four adaptation strategies assessed with coffee farmers, crop diversification was the preferred (53%). But when the likelihood of extreme weather events increased, coffee farmers chose using solar dehydrators (77%). According to the results presented in Table 15, solar dehydrator and IPM were also preferred strategies to invest in under normal weather conditions. In addition, coffee farmers willingness to invest in solar dehydrators increased significantly in Phase II (McNemar X^2=4.92, p<0.05).

By contrast, there was lower willingness to invest in IPM in Phase II (50%). Coffee farmers' decisions in the group playing with IPM was evenly distributed in both stages of the game; the difference between the two phases was not significant (McNemar X^2=0.00, p>0.1).

Similarly, the strategy of crop diversification did not present a significant difference in the choices of the participants throughout the game (McNemar X^2=1.78, p>0.1). The reason for this non-significance can be that coffee farmers decided to invest in this strategy even with normal climate variability, which indicates that they are willing to diversify their crops regardless the weather conditions.

Table 15. Coffee farmers' decisions to invest in each adaptation strategy

	Normal climate variability *p = 0.25*				Climate change *p = 0.4*			
	Do not adapt		Adapts		Do not adapt		Adapts	
	Number Observations	%	Number Observations	%	Number Observations	%	Number Observations	%
Beekeeping	19	63.33	11	36.67	8	26.67	22***	73.33
Crop diversification	14	46.67	16	53.33	9	30	21 n.s.	70
Integrated pest management	16	53.33	14	46.67	15	50	15 n.s.	50
Solar dehydrator	16	53.33	14	46.67	7	23.33	23**	76.67

*** significant at 99%, ** significant at 95%, n.s. not significant

The investment decisions for beekeeping doubled in Phase II, whereby the difference was significant (McNemar X^2=7.69, p<0.01). This result indicates that coffee farmers will be willing to invest in beekeeping to increase their incomes in times of climate change.

In addition, coffee farmers also take into account the cost required to invest in them. The Pearson Coefficient (r = -0.55) for this group of farmers demonstrates that there is a substantial negative relationship between the implementation cost and the investment in adaptation; suggesting that investment decisions are considered when the investment cost is moderate.

6.1.3.2. Cocoa

The differences in the responses of cocoa farmers between Phases I and II were not significant except for the strategy of crop diversification (McNemar X^2=5.82, p<0.05) (Table 16). These results differ from the results found in Table 13 that demonstrate that cocoa farmers prefer investing when the probability of experiencing climate change is higher. When analyzing the aggregate responses, it is found that cocoa farmers are not risk takers and prefer to adapt anticipatively to the impacts of climate change, but the disaggregated results (analyzing the strategies separately) suggest that there is no relationship between the decision to invest and the likelihood of bad weather. In other words, apparently the decision to invest does not depend on the weather.

Table 16. Cocoa farmers' decisions to invest in each adaptation strategy

	Normal climate variability *p = 0.25*				Climate change *p = 0.4*			
	Do not adapt		Adapts		Do not adapt		Adapts	
	Number Observations	%	Number Observations	%	Number Observations	%	Number Observations	%
Beekeeping	10	33.33	20	66.67	8	26.67	22 n.s.	73.33
Crop diversification	17	56.67	13	43.33	8	26.67	22**	73.33
Drip irrigation	15	50	15	50	15	50	15 n.s.	50
Integrated pest management	7	23.33	23	76.67	2	6.67	28 n.s.	93.33

** significant at 95%, n.s. not significant

Observing the data in Table 16, cocoa farmers invested more during Phase II, in the strategies of beekeeping, crop diversification and integrated pest management. The investment decisions in drip irrigation remained the same. However, comparing the responses with the other two crops, cocoa farmers were the ones who invested the most in adaptation during the two phases (Tables 15, 16 and 17). In fact, the investment in IPM reached 93% in Phase II, which is the highest investment in all the strategies among the three crops. This behaviour explains why the differences were not statistically significant and at the same time indicates that cocoa farmers do prefer to invest in adaptation and a little more when facing climate change.

Their attitude to drip irrigation systems was indifferent in the sense that half of the decisions opted to invest and the other half not to invest. The same distribution was observed in Phase II (Table 16). This behaviour suggests that the motivation to invest in this strategy is unrelated to climate variability. Indeed, neither is related to the cost of investment, for according to the Pearson Coefficient (r = 0.08) there is no relationship between this cost and the percentage of adaptation. Thus, the motivation to invest in this strategy is more related to its benefits and its utility during the harvest cycle.

6.1.3.3. Citrus

As with cocoa farmers, a similar situation is observed in the results from citrus farmers (Table 17). Their decisions were not statistically different from Phase I to Phase II, which demonstrates that their willingness to invest in adaptation strategies is not related to climate variability. These results confirmed the findings in section 4.1.1.2 where there is no significant difference in the aggregated data. In addition, since the investment for almost all the strategies was reduced with climate change variability with no significant difference, one may infer that citrus farmers are risk takers as they do not want to pay the investment cost and they are expecting to have normal weather during the harvest period. In fact, taking into account that they had the two most expensive strategies (drip irrigation and soil conditioning) and that these strategies had the lowest levels of investments in both phases, this statement is confirmed.

Table 17. Citrus farmers' decisions to invest in each adaptation strategy

	Normal climate variability ***p = 0.25***				**Climate change** ***p = 0.4***			
	Do not adapt		Adapts		Do not adapt		Adapts	
	Number of Observations	%	Number of Observations	%	Number of Observations	%	Number of Observations	%
Beekeeping	7	23.33	23	76.67	10	33.33	20 n.s.	66.67
Drip irrigation	14	46.67	16	53.33	17	56.67	13 n.s.	43.33
IPM	11	36.67	19	63.33	10	33.33	20 n.s.	66.67
Soil conditioning	19	63.33	11	36.67	24	80	6 n.s.	20

n.s. not significant

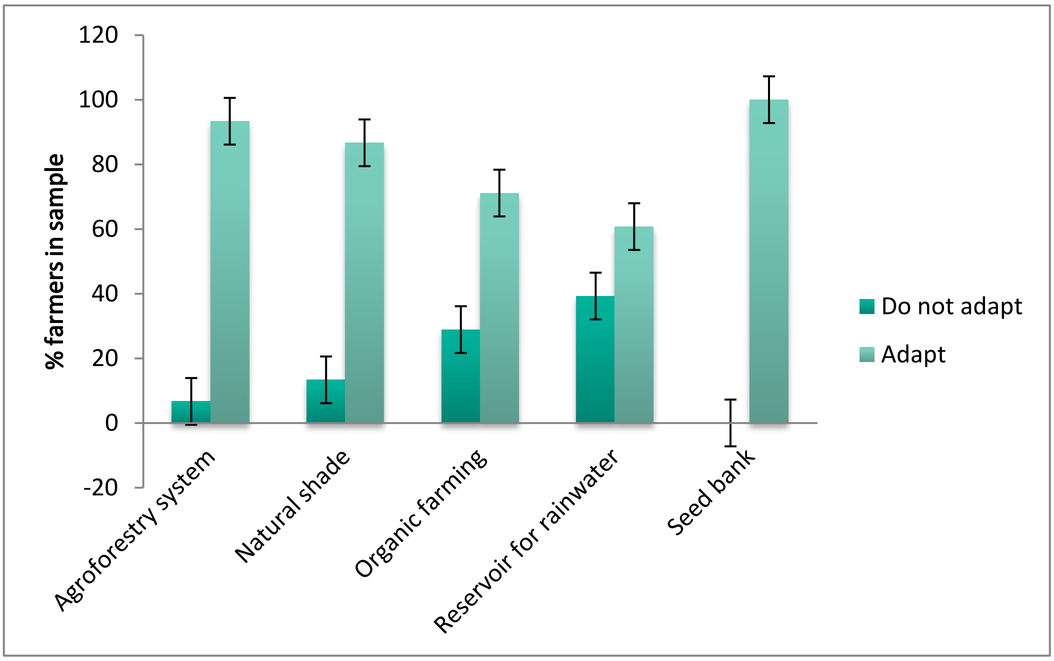
Indeed, the Pearson Coefficient (r = -0.7) indicates that there is a very strong negative relationship between the investment cost and the decision to invest in adaptation, which proves that citrus farmers did not want to adapt through soil conditioning and drip irrigation because of the high costs of these strategies.

6.1.4. Investment in adaptation of collective strategies

In Phase III, collective adaptation strategies were assessed. In this stage, farmers had the possibility to decide collectively whether to invest in adaptation options that might benefit more than one household or farmer. Besides, the total implementation cost was shared among the five participants of the group. This phase was designed to evaluate the willingness of farmers to get associative microcredits in order to invest as a group in adaptation.

Analyzing the aggregated data, presented in Table 10 at the beginning of this chapter, it is observed that farmers are willing to invest in adaptation associated with other farmers, seeking to share the benefits and costs of the adaptation strategy. Figure 9 presents the average percentage of adaptations made on each collective strategy.

Figure 9. Average percentage of adaptations in collective strategies during Phase III



Clearly, farmers behaved cooperatively and invested considerably in collective strategies. On average, 82% of farmers adapted, which is significantly higher than those who did not (18%). In fact, all farmers playing with the option of seed banks decided to invest in all rounds. The reservoir for rainwater collection was the strategy with the lowest values; however, there is a moderate difference of 21% in favour of adaptation over no adaptation.

Comparing the responses between Phases II and III, there is a significant difference (McNemar $X^2 = 30.06$, $p<0.001$) that confirms the cooperation of farmers to invest in adaptation. But as these results represent general decisions, it is important to explore the behaviour of farmers for different crops when cooperation is an adaptation option. Table 18 introduces the responses by crop.

Table 18. Adaptation decisions in collective strategies by crop

	Coffee				**Cocoa**				**Citrus**			
	Climate change		Cooperation		Climate change		Cooperation		Climate change		Cooperation	
	Number of Obs.	%	Number of Obs.	%	Number of Obs.	%	Number of Obs.	%	Number of Obs.	%	Number of Obs.	%
Do not adapt	39	32.5	17	9.44	33	27.5	45	25	61	50.83	51	28.33
Adapts	81	67.5	163	90.56	87	72.5	135	75	59	49.17	129	71.67
Total of Observations	120		180		120		180		120		180	

The willingness to invest in adaptation was higher in all three crops in the cooperation stage. The greater difference in responses is observed in coffee farmers' decisions (23%), followed closely by citrus farmers (22.5%). Clearly, coffee farmers are those who chose adaption as the first option with 90% of the decisions. Cocoa farmers did not show great preference for investing in the collective strategies as the percentages of responses in the two phases are similar (only 2.5% of difference). However, these responses depend on the strategies assigned to each crop hence it is relevant to evaluate the decisions taken for each strategy.

6.1.4.1. Preferences of collective adaptation strategies according to the crop

Six collective strategies were assessed in this stage from which the most preferred for the three crops was the agroforestry system with 93.3% of the responses, as indicated in Table 19. Although seed bank strategy a 100 percent adaptation rate, it was evaluated only with citrus farmers; by contrast, the agroforestry system was assessed in all the crops. The less preferred strategy was the construction of a reservoir for rainwater with almost 61% of the responses.

Table 19. Number of adapts for each collective adaptation strategies by crop

	Coffee			Cocoa			Citrus			General		
	Number Obs.	%	Total Obs.	Number Obs.	%	Total Obs.	Number Obs.	%	Total Obs.	Number Obs.	%	Total Obs.
Agroforestry system	45	100	45	36	80	45	45	100	45	126	93.33	135
Natural shade	42	93.33	45	36	80	45				78	86.67	90
Organic farming	36	80	45	45	100	45	15	33.33	45	96	71.11	135
Reservoir for rainwater	40	88.89	45	18	40	45	24	53.33	45	82	60.74	135
Seed bank							45	100	45	45	100	45

Analyzing the preferences according to crop, it is observed that coffee farmers opted to invest in all four strategies assigned to them. Agroforestry system and natural shade were the two strategies with the greatest levels of adaptation; however, organic farming and the water reservoir were also selected by more than 80%. All coffee farmers playing with agroforestry system decided to invest in this strategy in all rounds of the game. Similar situation is found with citrus farmers who always decided to invest in this practice. Other strategies chosen by all members of the group during all rounds are organic farming by cocoa farmers and seed bank by citrus farmers.

A reservoir for rainwater as an adaptation strategy was not very popular. Cocoa farmers opted for it in 40% while citrus farmers in 53%. By contrast, almost 90% of coffee farmers' responses opted to invest in it. Similarly, organic farming was not attractive enough for citrus farmers to adopt this practice as adaptation.

6.2. Surveys with farmers

A total of 60 surveys were conducted with all farmers who participated in the EEGs. The information gathered in the surveys helps to understand some of the decisions that farmers took during the games where they were asked for general information on their economic activities, households, perceptions of the weather and effects of climate change, and their access to financial services. The survey design can be found in Appendix 2.

Looking at the general information of the respondents, farmers on average were 46 years old and most were men (65%). Women who participated in the games were typically younger than men. As for the households of the participants, they comprised on average four people, two of whom contribute financially to the household. The largest household includes eight people of which four contribute financially.

All players were farmers who, on average, have been devoted to this economic activity for 26 years. Men dedicate more time to agriculture than women, as shown in Table 20. Although the main economic activity of participants is agriculture, many are engaged in other activities, working as members of the committee of coffee and cocoa, in businesses, bakeries, mechanics, transport and fisheries.

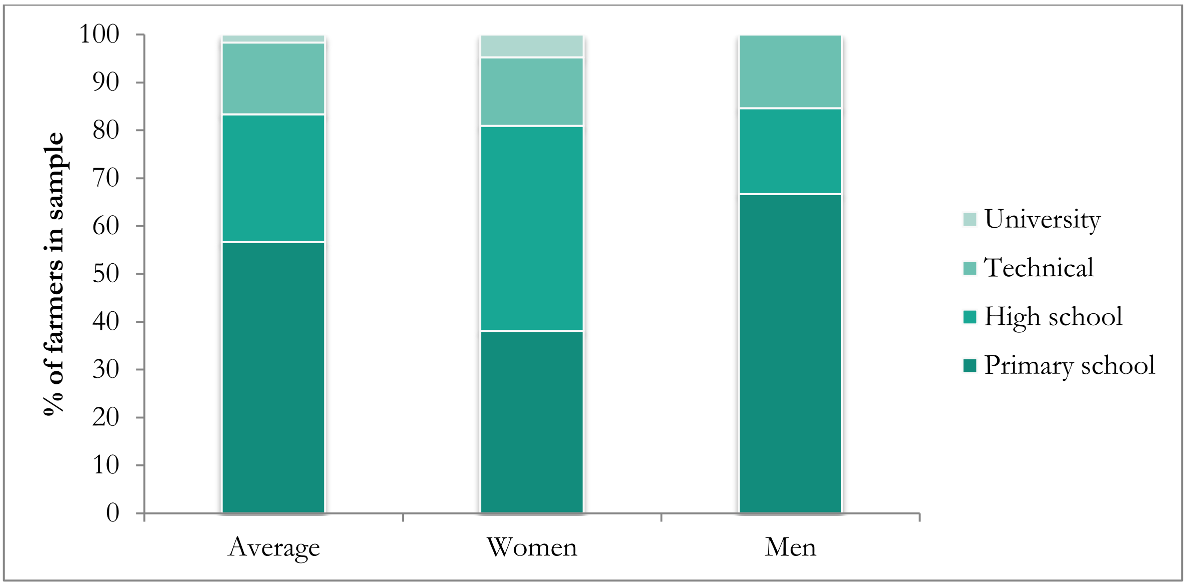
Table 20. General and financial information of the respondents

	General	Women	Men
Age	46	41.9	48.3
Gender (%)		35	65
Number of household members	4		
Number of members that contribute to the household income	2		
Time working in agriculture (years)	25.9	19	29.7
Willingness to invest in adaptation (%)	95	95.2	97.4
Willingness to acquire a microcredit (%)	88.1	90.5	86.8
People who applied for credit (%)	91.6		
Acceptance rate for credit applications (%)	98.3		

In addition to personal information, when asked about their willingness to invest in adaptation, 95% of farmers said they would not only be willing to invest in order to adapt to climate change, but 88% would be willing even to acquire a loan for this investment. In fact, contrary to expectations, access to financial services by farmers is quite high as more than 90% have already applied for a loan, of which 98% have been approved. The amounts, payments and times of these credits will be analyzed below in accordance to the crop to which the farmer belongs.

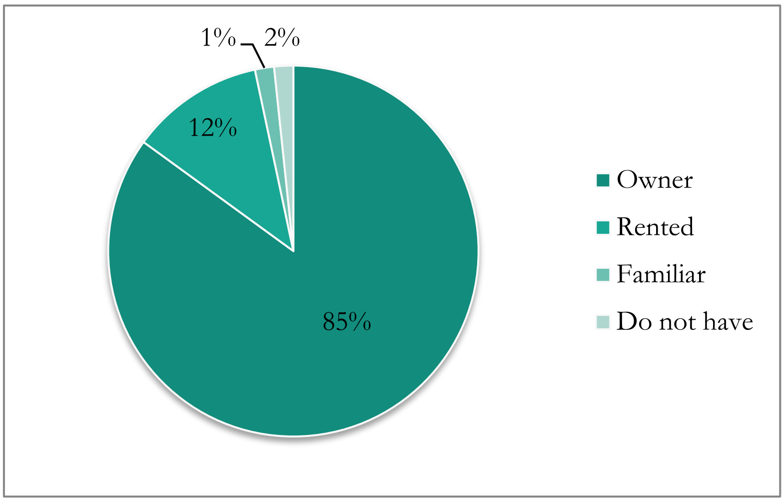
Other relevant information of respondents is their level of education, which according to Figure 10 is quite low as almost 57% studied until primary school and only 17% above high school (technical or university). An interesting fact is that women have higher levels of education than men, since there is a higher percentage of women who completed high school education and they are the only ones that have gone to college. Men's lower level of education could be a consequence of their engagement in agriculture from an earlier age, working in the fields instead of going to school. This also explains why men have been engaged longer in farming than women.

Figure 10. Education level of participants



Another important fact is the land ownership of farmers who participated in the EEGs. Looking at Figure 11, one finds that the vast majority of farmers own their land. This situation favours investment in adaptation because if the farmer does not own the land, probably he/she will not want to make an investment as the returns may be realized only in the future. Also, if the investment involves changes in infrastructure, planting and soil suitability is easier if the farmer invests in a land that he owns. Indeed, some of the farmers working on land leased said they would not invest in strategies such as water reservoirs because they have no land where to build.

Figure 11. Land ownership



6.2.1. Survey results according to crop

Given the particularities of each crop in terms of duration of harvest, the marketed product, cultivated areas and the revenues and costs of production obtained, it is relevant to distinguish certain data according to the crop. To do this, Table 21 presents the data obtained from surveys by crops.

In general, farmers who participated in the EEGs have, on average, a little more than three acres of cultivated area where they not only grow cocoa, or coffee or citrus, but also cultivate them with other crops. Usually, coffee and cocoa farmers combine their product with citrus crops, cassava, banana and avocado. Cocoa and citrus farmers have the largest land area cultivated with just over four hectares; in contrast, coffee farmers cultivate on average one hectare and a half. In fact, the respondents' cultivated area in coffee crops does not exceed two hectares, while some farmers own up to 12 hectares of cocoa or citrus.

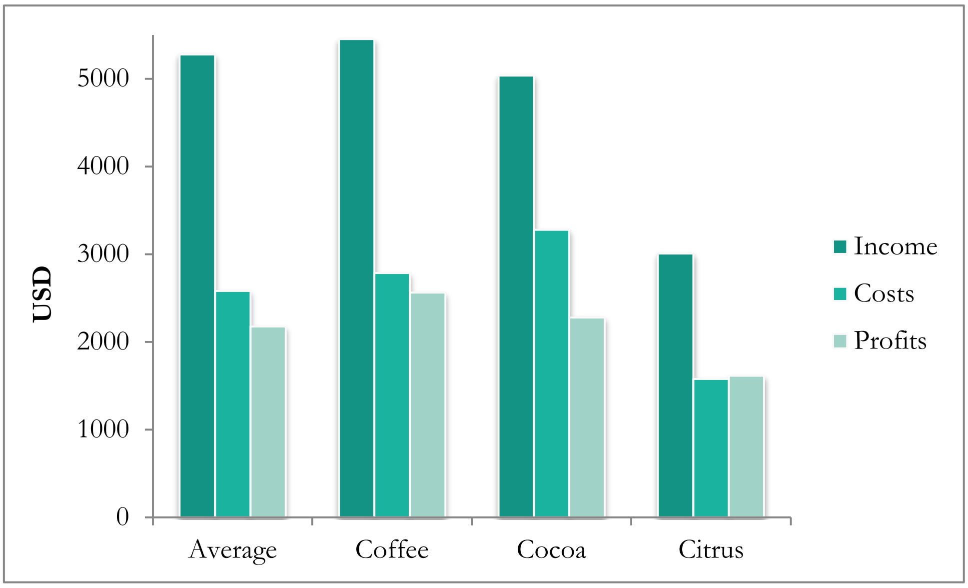
Table 21. Survey results according to crop

	General	Coffee	Cocoa	Citrus
Cultivated area (ha)	3.28	1.61	4.22	4.21
Minimum cultivated area (ha)	1	1	1	1
Maximum cultivated area (ha)	12	2	12	12
Number of harvests per year		1.5	2	3.7
Monthly household income (USD)	1,130	942	1,292	1,158
Perception of poverty / wealth	3.7	3	4	3.9
Amount of credit that farmers have been taken (USD)	5,184	3,685	7,515	4,618
Credit period (years)	3.8	4.4	4.3	2.6
Monthly payment of the loan (USD)	114	70	146	148
Maximum monthly payment farmers are willing to make (USD)	119	133	154	155

The number of harvests in one year also varies according to the crop. Cocoa has on average two main harvests and coffee may have one or two harvests. In the case of citrus it varies, as these farmers grow orange, tangerine and lemon. Usually, they have two main harvests per year, but 15% of citrus farmers stated that they have permanent harvest since they grow several citrus products.

Given the differences between crops (acreage, number of harvests and product), the marketing of products also yields different results (Figure 12). Although the income of farmers surveyed is on average USD 5,278 per harvest, income perceived by citrus farmers in one harvest is the lowest (USD 3,007). However, considering they have as many crops per year (Table 21), their yearly income could surpass those of another crop. Their monthly household incomes are higher than the income of coffee farmers, as shown in Table 21. Revenues of coffee and cocoa crops are similar (USD 5,450 and 5,037, respectively), although coffee farmers receive on average USD 413 more per harvest as is observed in Figure 12.

Figure 12. Average income, costs and profits of each harvest of the crop



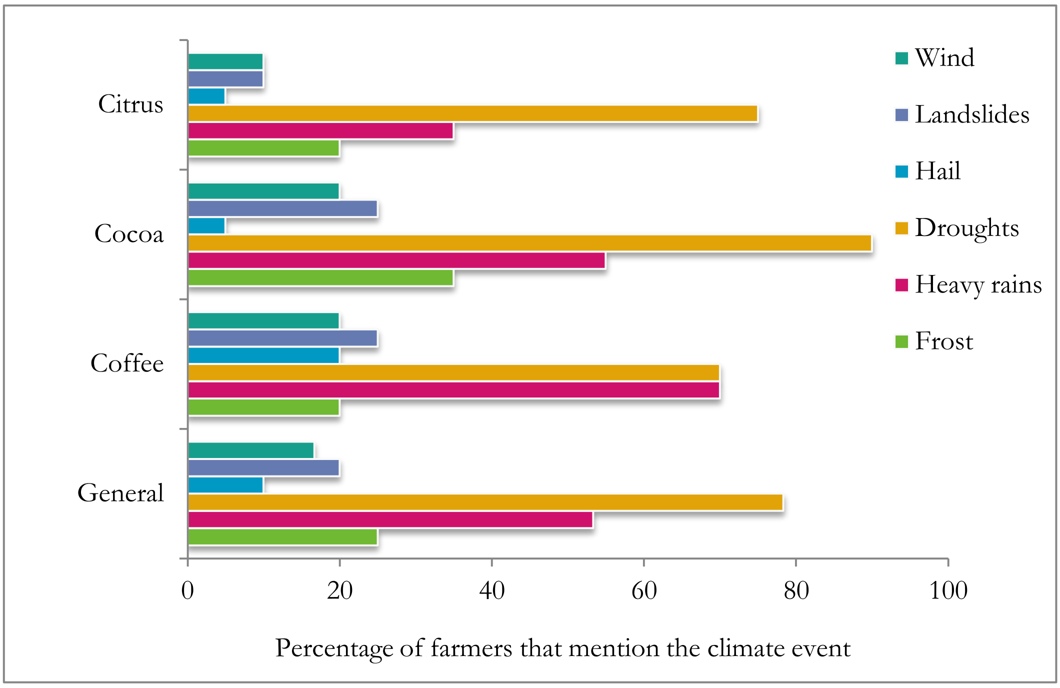
Revenues received from each harvest do not necessarily reflect the utilities from it, as farmers must also pay the costs of production. Figure 12 also presents the costs and profits for each respective crop. The higher costs are for the cultivation of cocoa (USD 3,276) representing 65% of the income of farmers and they are above the average of the three crops. This causes cocoa farmers to get the lowest profits. Although citrus farmers have the lowest costs (USD 1,579), they represent a little more than half of income. Thus, farmers who get higher profits are coffee farmers (USD 2,561) which are above the average of all respondents (USD 2,174).

Regardless of profits and revenues that farmers receive for their harvests, in the survey they were asked about their perception about how rich or poor they are relative to other households in the community of Rionegro. They were asked to choose on a scale from 1 to 10, where 1 represents the poorest households and 10 the richest of the community. Farmers located themselves with their families between 3 and 4 on the scale (Table 21), reflecting a moderate perception of poverty. If their monthly income is compared to the legal minimum monthly income of Colombia in 2014 of USD 308, the household incomes of the three crops are above this value. However, farmers stated that such income is received in times of good weather that does not significantly affect their crops and therefore does not generate losses. But when climate change affects rainfall patterns and creates sudden changes in temperature, crops are at great risk and are even more vulnerable which may significantly reduce the monthly income.

According to responses, drought and heavy rainfall are the climatic events that most affect crops (Figure 13). Frost affects mostly cocoa farms. But it is important to clarify that for farmers frost does not refer to the presence of haze, but seasons with very low temperatures and cold (Sánchez, interview). Also, hail refers to morning dew or very soft rains that wet the leaves of the trees (Santos, interview). This gentle rain promotes the proliferation of pests and insects in some crops of coffee.

Since cocoa and coffee are located on steep hills and slopes, landslides are threats that affect these crops considerably and occur mostly during heavy rains in the rainy seasons. Besides, windstorms are another threat that generates erosion in the mountains, reducing the area available for cultivation.

Figure 13. Climate events that most affect the crops



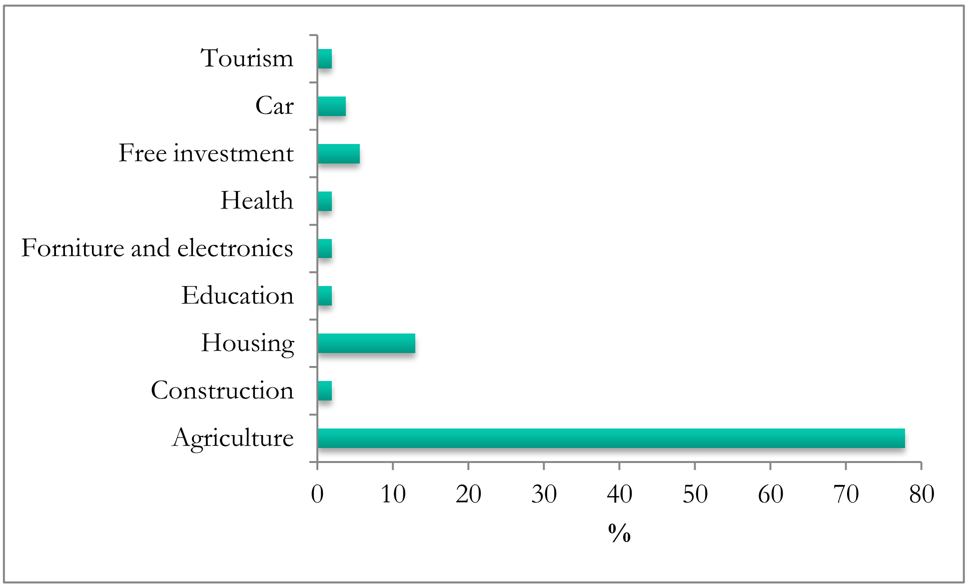
As mentioned above, farmers already have considerable access to financial services. According to the results presented in Table 21, farmers have on average loans of USD 5,184 for a time of almost four years. The monthly payment that generates these credits is USD 114. These credits have mostly been through the Agricultural Bank (government bank for agriculture) and they are non-microfinance products. Some farmers stated during the survey that they currently have loans with the Microfinance Institution Crezcamos.

These results also show that cocoa farmers have had loans with higher amounts (USD 7,515); coffee farmers have an average of USD 3,685 in credits and citrus farmers USD 4,618. Another interesting data obtained from the surveys is the maximum monthly payment that farmers are willing to make, a value higher than the monthly payments of the loans that farmers of the three crops have had.

If monthly payments associated with the investment cost of different strategies in the EEGs are compared, it appears that the costs assigned to the strategies are close to the range of payments that farmers have already paid in their loans with the Agricultural Bank and other financial institutions. The investment costs in the games corresponded to six monthly payments, given that on average a harvest lasts six months and that these costs were necessary investment for a harvest. Hence, investment costs in the EEGs ranged USD 400 - 1,100 and six payments of the loans of farmers ranged USD 714 - 930. Strategies that are above this range are drip irrigation and soil conditioning, which explains why farmers chose not to invest in these strategies regardless of the state of the climate.

The credits taken by farmers have been intended for different purposes, as shown in Figure 14. The predominant purpose is agriculture: nearly 80% of farmers have applied for credits related to this economic activity. Far below this percentage, housing appears as the second important purpose farmers mentioned.

Figure 14. Purposes of loan that farmers have taken



6.3. Interviews

6.3.1. Interview with a member of the Microfinance Institution Crezcamos

An interview was conducted with Jaime Andrés Osorio, Director of Methodologies and Products of the Microfinance Institution Crezcamos who said that since its inception, the MFI was created for rural markets. Its focus is to offer credit to farmers.

The interest in providing products that protect the environment and are ecosystem-based arose from the overall objective of the company which seeks to promote client protection through appropriate and responsible products (Crezcamos, 2014). Crezcamos conducts a solvency study of the customer to know his/her ability to pay and determine the most suitable product. The social responsibility of the institution entails offering environmentally friendly products and promotes sustainable agriculture. That is where the MEBA Project and Crezcamos join to offer strategies for farmers to adapt to climate change through microfinance products.

According to Osorio, the responsiveness of farmers to these microfinance products is good. Nonetheless, Osorio says that the agricultural market in Colombia is monopolized by the Agricultural Bank, as it has control of the financial sector to agriculture. Crezcamos through microfinance provides enhanced financial services relative to the Agrarian Bank in terms of transparency, flexibility and ease of access. Osorio explains that these three aspects are essential for the farmer. Usually, when the farmer wants to invest in working capital, as inputs for cultivation, he/she requires very fast financial resources and cannot wait a month or two to have the credit approved, as with the Agricultural Bank.

According to Osorio, investment in agriculture must be made almost immediately. For instance, if the farmer did not invest in fertilizers at the beginning of harvest, the farmer will not be as productive. Likewise, if he/she does not invest in inputs like crop protection, the crop may be more vulnerable to pests and climatic events. In this sense, Crezcamos is more efficient since it takes 2-8 days to approve a microcredit.

Another advantage of microfinance besides the speed with which credits are approved, is the ease to acquire them. Osorio explains that the Agricultural Bank provides loans only to farmers that own the farm and have more than 10 hectares of cultivated area. Instead, Crezcamos offers products to small farmers who cultivate 1 or 2 hectares, maybe grown in leased land. Thus, possession and acreage are not reasons to grant or deny credit. Osorio says that the only reason not to grant a loan is if customer information is inconsistent or if information is withheld. In addition, the required documents are easy to obtain and even a business advisor can get them on the farmers' behalf.

Osorio acknowledges that the interest rates of other financial institutions such as the Agricultural Bank are higher than those offered by Crezcamos. But he claims that microfinance does not compete with interest rates but with the service and agility. In this case, Crezcamos sends a marketing executive to the customer's farm for a full study of the agricultural unit. The study covers housing conditions and, the type of crop and profits it generates, among others. Thus, the farmer will receive the appropriate amount of loan. Osorio also explains that microcredit is designed for capital investment in the short and medium term. Long-term loans require very low interest rates, and generally, farmers use them to buy assets such as farms. Osorio says that on average credit granted to farmers by Crezcamos is USD 1,400 and a term of 20 months and a monthly interest rate of 3.08% is set.

Regarding the farmers' constraints to access credit, Osorio mentioned that the only limitation is the coverage area. Nowadays, Crezcamos business executives go to farms located maximum two hours far from the office of Rionegro. To address this limitation, Crezcamos is creating 'non-banking correspondents' who are associations with different retail entities that allow farmers to make the monthly payment of the credit at any store or retail outlet.

In addition to microcredit, micro-insurance is another product that could help farmers adapt to climate change. The purpose of insurance is to protect farmers assets', since they have high capital invested in their crops. In fact with a single weather event, the farmer could lose a great portion of the capital he/she has invested in the farm.

Crezcamos has designed some insurance to mitigate the effects of climate change such as drought, rain, frost and strong winds. Osorio said the farmer insures maximum three weather events and that the policy covers the entire crop. If any of these events occur, the insurance will pay a value for each destroyed or damaged plant.

Osorio also states that the Colombian government has allocated subsidies to farmers to get insurance, which range between 60 and 80% of the policy. Thus, the farmer pays the remaining value because the total cost of insurance is very high. Although Crezcamos has not yet implemented these insurances, it is conducting a publicity campaign to motivate farmers to include insurance in the cost of inputs required for each crop.

Osorio thinks that a strategy to improve farmers' productivity is to establish partnerships. This means reducing the number of intermediaries in the marketing chain to increase the percentage of the crop's value received by farmers since currently that stands only at 10% of the market price. Osorio even proposes that farmers could produce their own products for sale under their own label.

Another way to improve agriculture is through training. Osorio thinks that training is essential to implement adaptation strategies evaluated in this thesis. So, the farmer can learn to install, maintain and implement such strategies. Furthermore, Crezcamos will offer free training to farmers who wish to invest in adaptation, and personalized support will be conducted with each farmer.

Finally, Osorio says that there is a possibility of offering associative credits to farmers that belong to agricultural corporations. Indeed, they have already had discussions with the Association of Coffee and Cacao to provide group loans.

6.3.2. Interview with a coffee farmer

An interview was conducted with the Director of the Coffee Farmers Departmental Committee, Mr. Héctor Santos. In the interview, Mr. Santos was asked about the agricultural practices used in coffee growing. Farmers use chemical fertilizers because it is cheaper than organic fertilizers. Santos explains that when using chemical fertilizers a total of 200g of chemical fertilizer is needed per hectare in one harvest, in contrast with 1,000 g organic fertilizers for the same period and area. If there were possibilities to access cheaper organic fertilizers, farmers would use them as they favour soil structure by improving soil quality and productivity. This explains why in the economic game farmers were willing to invest in organic farming and in agroforestry systems.

Regarding the major threats that affect coffee cultivation, Santos stated that extreme climates droughts and winter affect the crop in a different way. The former dehydrates and deteriorates the grain and favours the proliferation of *Hemileia vastratrix*, a plague that kills growing coffee. By contrast, if winter brings heavy rains in the blooming period of the plant, the plant will not bloom as it needs sun and dry weather. For instance, Santos claimed that in 2013 the wet season came early (during the blooming season), as a consequence of climate change, and coffee farmers lost all their harvest. It is for this reason that having natural shade in excess is not completely healthy for the coffee plant. Santos states that coffee plants need shade but in a moderate way.

Regarding other adaptation strategies, Santos states that farmers actually use a similar type of dehydrators to those proposed in the EEG that allow to dry coffee beans at any time of the year irrespective of the weather. Hence, coffee farmers understand that in times of climate change solar dehydrator are the most efficient. He also said that a seed bank is useful to mitigate the impacts of climate change since they can select the best and more resistant seeds. Indeed, the National Federation of Coffee Farmers has a research department where seeds resilient to diseases and extreme weather are produced and distributed to farmers.

6.3.3. Interview with a cocoa farmer

An interview was conducted with one of the leaders of the Cocoa Farmers Association of Rionegro, Mr. Francisco Sepúlveda. He explained that cocoa farms also use chemical fertilizers, and some farmers combine them with organic fertilizers. Mr. Sepúlveda has a pilot project on his farm where he uses only environmentally friendly resources. For example, he makes compost from poultry manure, which in turn generates a biological control to eliminate pests that affect crops. Sepulveda states that this type of fertilizer is cheaper than chemical fertilizer and also favours the constant production of the crop, whereas chemical fertilizers damage the tree.

Another agricultural practice used by Sepúlveda is irrigation from a well on his farm. Sepúlveda looks after that water well through tree planting, such as *Heliconia L.*, which help retain water, conserve and create microclimates. Consumption of this water is minimal, since a micro-spray system that sends the exact amount of water to each plant is used. According to Sepúlveda the drip irrigation system is not very efficient because it increases soil salinity by depositing drops always at the same place. It is for this reason that this strategy was not preferred in the decisions of cocoa farmers in the EEG.

As for the rainwater reservoirs, Sepúlveda says it is a good strategy to channel water into a pond. However, he claims that farmers do not make efficient use of water since in rainy seasons there is greater consumption instead of saving for the dry seasons. Furthermore, the use of chemical fertilizers and pesticides contaminates rivers and streams. All good agricultural practices implemented by Sepúlveda are being popularized by the Cocoa Farmers Association so that other farmers can implement them.

Sepúlveda thinks that it is important to introduce other productive activities on farms, such as beekeeping, fishing, pigs, chickens and cattle, for animals help control weeds, pests, and marketing products derived from them increases farmers' income.

6.3.4. Interview with a citrus farmer

An interview with a citrus farmer, Mr. Gilberto Sánchez, a leader of the community was also conducted. Mr. Sánchez explained that among the agricultural practices used for growing citrus, the most frequently used are gravity irrigation and organic and chemical fertilizers. From the survey results, it was found that farmers tend to combine citrus cultivation with poultry. The reason for this is to use poultry manure as organic fertilizer for growing citrus. According to Sánchez, this is the most widely used organic fertilizer as it is very cheap and farmers can decompose it. However, this organic fertilizer should be mixed with chemical fertilizers because, according to Sánchez, its high utilization of generates a plant disease called "Alternaria".

The management of water resources in this crop is mainly handled with a gravity irrigation system. Since citrus fruits are grown on slopes, this system is quite useful as it distributes the water throughout the crop by hoses without a pumping system. Sánchez says that the irrigation water comes from nearby streams. To make use of such water, it is necessary to apply for a permit from the Corporation for the Defence of the Plateau of Bucaramanga (CDMB), the institution responsible for the management of renewable natural resources and the environment (CDMB, 2014), which authorizes the construction of a water reservoir with water use of a nearby creek. Sánchez claims that the annual cost of using that water does not exceed USD 2 per year, which is a fairly inexpensive measure.

According to Sánchez, the drip irrigation system is useful because it saves 30% in water consumption, but very few farmers use it at this time, given the high cost of implementation ranging in USD 3,000-6,000 per hectare. In fact, Sánchez confirmed that this was the reason that citrus farmers did not invest in this strategy in the economic games. In this sense, it is necessary to acquire a loan to install the irrigation system on their farms. Also, if this cost is compared with the minimum cost of using the water of the creek, there would be a greater incentive to implement the drip irrigation system, unless the availability of water in the streams is diminishing.

In fact, Sánchez says that climate variability is increasing, which limits the weather forecast and the ability to know when it will be the rainy and dry seasons. As a result, the greatest threats are the mite that proliferates with abrupt changes in the pattern of rainfall, and long dry seasons. Sánchez claims citrus trees require watering every day and that the lack of water deteriorates the plant almost immediately.

Measures that could best help farmers adapt to climate change are a suitable irrigation system and studies of soil structure to find out what the most beneficial organic fertilizers are, Sánchez says. In addition, farmers should associate to create a corporation. Unlike the coffee and cocoa cultivation, there is no organization to promote the economic activity of citrus farmers. Sánchez also thinks that an easy payment credit would help to invest in irrigation systems to reduce water consumption and prevent overexploitation of water resources in the region.

7. Discussion

The overall objective of this thesis is to analyze how the risk of experiencing climate change conditions influences the willingness of Colombian farming communities to invest in strategies to adapt anticipatively to climate change. This objective is achieved by answering three research questions: i) how potential changes in climate variability as a result of climate change, influence the willingness to invest in adaptation strategies by farmers, ii) what adaptation strategies are the most relevant to adapt to climate change in these communities; and, iii) what is the willingness of farmers to implement these strategies through microfinance products. To answer these questions and achieve the overall objective of the thesis, surveys, interviews and experimental economic games with farmers of three different crops coffee, citrus and cocoa were performed.

The first important finding obtained from the economic games is that farmers tend to prefer adapting when the likelihood of extreme weather events, that might affect their harvests, increases. It suggests that farmers are risk averse to tackling climate change as they want to be prepared to extreme events, such as heavy rains, droughts, strong winds, landslides and flooding. This agrees with the results of Alpízar *et al.* (2011) in the case of coffee farmers in Costa Rica, who not only found high levels of risk aversion but also observed farmers making tradeoffs during their experiment by not adapting at low risk levels. Similarly, tradeoffs were also observed in farmers' behaviour during the economic games.

Farmers demonstrated that climate variability is not the only reason to invest in adaptation, but also the risk of damage from that variation and the cost to adapt. From all proposed strategies, farmers did not invest significantly in the two of the most expensive, drip irrigation and soil conditioning. In fact, farmers' reduced their investment in these strategies when they were facing the increased likelihood of climate change. This decision is closely related to the maximum monthly payment that farmers are willing to make according to their responses in the surveys. Farmers invested in those strategies whose implementation costs do not exceed this value, except for drip irrigation and soil conditioning strategies whose costs are higher. This behaviour supports the findings of Binswanger and Sillers (1983) who argue that risk aversion and constrains in credits approval limit the investment decisions of farmers to new technology.

Besides the cost of adaptation, the expected return on the investment plays an important role in adaptation. Although the experiment assumes that the benefits of the strategies are perceived almost immediately, farmers know that some strategies last more to show results. They stated their interest in strategies where the return and the benefits are perceived in the short-term such as beekeeping, solar dehydrators, crop diversification and IPM. However, farmers are aware that there are more efficient strategies that require longer periods to observe their benefits as is the case of soil conditioning, natural shade and agroforestry system; thereby, they are also interested in make long-term investments.

The ability to tackle climate change's impacts and to generate income is also a relevant factor that influences investment decisions. In this regard, farmers took different decisions according to the adaptations strategies proposed and its expected benefits. Some strategies were chosen regardless of the expected weather, others were preferred under increased risk of climate change and yet others were not selected by a significant number of players. These preferences answer the second research question of this thesis.

IPM and beekeeping were strategies preferred by farmers under any climatic conditions. This is because IPM is a generally necessary practice to protect crops from pests during the entire growing season. In addition, some climate change related events such as heavy rains favour the proliferation of pests (Ortíz and Pradel, 2009). Beekeeping can be implemented in any type of weather; it was preferred by farmers perhaps for its potential to generate alternative income from the sale of honey and propolis. Kasina *et al.* (2009) estimated that beekeeping contributes in almost 40% to the total annual income of small farmers who use this practice in their farms. In addition, this strategy provides ecosystem services such as pollination and increased biodiversity.

Hence, in times of climatic events affecting the crop, farmers could use beekeeping as an alternative source of income to offset the loss of income due to crop damage or failure, and in times of good weather it would increase farmers' income.

Crop diversification and the installation of solar dehydrators were the most preferred strategies when farmers faced climate change. The former diversifies the risk of loss by growing several crops at the same time. Therefore, in case of unfavourable weather the farmer may lose some of the crops and related income, but other crops may do better. The latter is useful even in times of heavy rains as solar dehydrators do not require much sunshine and also use the air currents as a drying method.

Another interesting finding is that farmers were most willing to invest in adaptation when they must decide collectively in a group. They preferred investing in agroforestry system, natural shade and seed banks. These strategies would help adapt anticipatively to climate change. For instance, a seed bank could store seeds resistant to extreme weather. Coffee farmers mentioned that the National Federation of Coffee Farmers has created a research centre for genetically modified coffee seeds that might be able to resist pest infestations, heavy rains and long periods of droughts. However, the introduction of GMOs represents other types of risks to agriculture through its impacts on food security, health and environment such as soil deterioration, biodiversity loss, and economic dependence on developed countries and multinational corporations that provide the seeds (Anderson *et al.,* 2001; Schmeller and Henle, 2008; Oguz, 2009).

During the conversations they had to make investment decisions, farmers analyzed the benefits, advantages and disadvantages of collective practices. In cases when farmers had experience using some of the practices being discussed, this experience was taken into account when making a decision. This was also observed by Bandiera and Rasul (2006), in Mozambique, who found that the adoption of new agricultural technology is motivated by the earlier experience of choices of others who have already implemented it. This way, farmers learn to use new technology from the experience and knowledge of others through social learning that promotes adaptation.

As every crop has its own agro-climatic and ecosystem requirements such as sunlight, temperature, soil fertility and moisture, farmers' decisions changed according to the crop they grow. Cacao farmers were willing to invest the most regardless the weather, while coffee farmers preferred investing taking climate change more heavily into account. By contrast, citrus farmers did not invest significantly in adaptation strategies and they even reduced their investment when facing climate change. This behaviour is consistent with the behaviour of some farmers during the experiment conducted by Alpízar *et al.* (2011) that indicated that these farmers are risk takers as they prefer to face the risk of losing the harvest rather than pay the cost of adaptation. This behaviour is also explained by the lowest annual income of citrus farmers among three groups.

Coffee farmers preferred investing in crop diversification and integrated pest management at any climate variability. But, when the likelihood of extreme weather events increased they chose using solar dehydrators and beekeeping. When deciding in a group, agroforestry systems and natural shade were the two strategies with the greatest level of adaptation.

For cocoa farmers the investment decision depends neither on the weather nor the implementation cost. However, they invested significantly in adaptation at any probability of extreme weather events. At the same time, according to the survey results, they earn the highest monthly income and their annual profits are also over the average, which allow them to make bigger investments. The most important reason why cocoa farmers invest in adaptation is because of the expected benefits of the strategies selected. They invested in beekeeping, crop diversification and IPM. Taking into account the information obtained from the interview and conversations with cocoa farmers, they preferred more efficient micro spraying technology to irrigation systems such as drip irrigation and reservoirs for rainwater. Micro spraying uses minimum amounts of water and covers a larger area at the base of the plant compared to drip irrigation. In addition, it uses non contaminated water by chemicals from fertilizers and pesticides which happen when using reservoirs of water from the stream. In fact, those farmers irrigating with stream water tend to consume more water as they do not pay for it, which is supported also by Escobar *et al.* (2013) who found that farmers increase their water consumption when the cost is low and when they perceive shocks in climate variability such as lower precipitation. This problem is also observed in citrus farmers' behaviour whose major source of water comes from streams.

Free access or very low cost water reflects the lack of a proper management of water resources from the local government. While one might think of free or low cost water as supporting agricultural production, this policy often ends up damaging water resources, not only because farmers tend to use more water than needed, but also because it may result in increased pollution of rivers and streams (e.g., nutrient pollution via increased runoff). This also affects populations downstream that use the water for household consumption. Furthermore, besides the unrealistically low cost of water, there is also no tax on the pollution generated by farming. Such management of water resources is unsustainable as it contributes to the deterioration of water resources. In addition to ecosystem and economic impacts, this may lead to increased major implications on the health and hygiene of the populations.

Although citrus farmers preferred investing in beekeeping and IPM, it is fundamental to design a suitable irrigation system that creates awareness of water consumption. The training to be conducted by the MFI Crezcamos to implement the adaptation practices should be accompanied by an awareness campaign to promote a responsible and sustainable use of water. Otherwise, the water availability will be compromised.

It is clear that the implementation of responsible irrigation systems and other strategies that are environmental friendly have high costs. Therefore, it is essential that farmers have access to microfinance services to implement them. To answer the third research question of this thesis, it was found that 88 percent of farmers appeared to be willing to make use of microcredit in order to invest in adaptation to climate change. This is supported because the vast majority of farmers own the land that allows them to make variations in infrastructure, planting and soil suitability. However, it was found that the access to microfinance services depends on the ease of obtaining credit and ability to pay.

The ability of farmers to pay depends on their income. Although farmers' income is higher than the legal minimum monthly income of Colombia, it is not constant throughout the year. Weather can lower or increase farmers' income according to its impacts on crops. Farmers stated that climate change affects rainfall patterns and creates sudden changes in temperature where crops are at a great risk and more vulnerable; this has the potential to reduce monthly income.

Regarding the ease of obtaining credit, the MFI Crezcamos stated that microfinance not only awards microcredits faster than regular commercial banks but also requires fewer documents from farmers. Taking into account that farmers often need rapid access to financing, easy and fast approval is a key advantage of microfinance. In addition, Crezcamos offers credits to small farmers who do not even own the farm and would not qualify for a loan at commercial banks or the Agricultural Bank of Colombia. Also, associative credits were viewed as a good option as farmers were willing to adapt cooperatively. These advantages of microfinance services represent important opportunities not only for the financial services industry to expand in rural areas, but also for enhancing and strengthening agriculture and promote food security.

Besides the implementation of adaptation strategies there are other options to improve the productivity of agriculture such as training and partnerships. Training will help farmers to learn about and understand better the benefits and advantages of the different strategies and to learn how to implement and manage them. The establishment of partnerships is fundamental to increase farmers' profits by reducing the number of intermediaries. Thus, farmers would receive a bigger portion from the final price of the product. In fact, farmers could introduce and create their own higher value-added finished products, including organic products under their own label and possibly certification.

Finally, regarding the design of the EEG, it is important to take into account that modifications in the experiment will lead to different results as it was designed with the specific purpose of assessing different adaptation strategies within specific agricultural communities. In this sense, modifications in the implementation costs might change farmers' decision as this variable is relevant in their decision making process. Also, an increase in the likelihood of occurrence of extreme weather events could further influence decisions and motivate farmers to invest in adaptation.

A relevant aspect of conducting experimental games with farmers is to guarantee their total comprehension of the rules and dynamic of the game. Considering that usually the education level of participants is lower, it was important to introduce the game with an easy to understand explanation, using appropriate language for the audience and pedagogic materials and ending with a round of questions to assure that the rules were clear to everyone. The promise is that experimental economic games can inform actual policy decisions based on information gathered from real users of the resources and people who experience daily the hazards of climate change and may know the best ways to address them. Indeed, given the relevance of the information obtained from farmers in the EEGs, the MFI Crezcamos has decided to make use of this methodology with other agricultural communities in order to start an implementation process of the most preferred strategies and to offer microcredits to those farmers willing to invest in adaptation.

8. Conclusions

It is not only the recognition by the Nobel Committee that gives authority to microfinance as a good strategy for adaptation to climate change, but the scope of microfinance to affect the life of millions of people (Hammill *et al.*, 2008). In countries like Colombia, where the government often fails to provide resources to the population affected by climate change, microfinance has real potential. Microfinance may not only reduce the vulnerability of affected populations to climate change but it could alleviate poverty by providing the poor a chance to build assets that are necessary in the face of all other forms of adversity. Under the right conditions, microfinance can thus be a double-edged sword, helping to combat both poverty and climate change.

In Colombia, agriculture is one of the most important sectors in the economy and there are many people who depend on it for their livelihood. Furthermore, it is precisely these people who are most affected by climate change because their agricultural production is sensitive even to small changes in climate. Although some adaptation actions have been implemented in Colombia, these responses are often reactive and autonomous and do not anticipate future impacts. Under such scenarios microfinance allows to plan adaptation to climate change as its portfolio of financial services accommodates the different needs of farmers who face the impacts of climate change.

On the other hand, it is equally important to understand what adaptation strategies in agriculture are appropriate and deserve attention from government and microfinance institutions. In this sense, this thesis research helped determine which strategies are accurate in the Municipality of Rionegro and improved the understanding of farmers' willingness to invest in adaptation according to the climate variability they are facing. Adaptation strategies such as IPM, crop diversification, beekeeping, efficient irrigation systems, agroforestry systems and seed banks require financing to be implemented. Based on the information obtained from farmers in the EEGs, the MFI Crezcamos has decided to continue using this methodology with other agricultural communities in order to start an implementation process of the most preferred adaptation strategies and to offer microcredits to those farmers willing to invest in adaptation. The EEGs represented an opportunity for farmers to realize the importance of investing in adaptation given the climate conditions they have experiences in the past and may increasingly face in the future.

Finally, microfinance can be even more effective when combined with programs that strengthen the human and social capital of communities, such as education and training programs and bottom-up strategies such as the establishment of partnerships, collective lands, social learning and social networks that would help farmers increase their earnings and reduce the number of intermediaries in the marketing chain. Therefore, a significant and sustainable investment and initiatives in adaptation in agricultural systems is crucial to limit the impact of climate change related risk and vulnerability; without such measures the food security of Colombia could be compromised.

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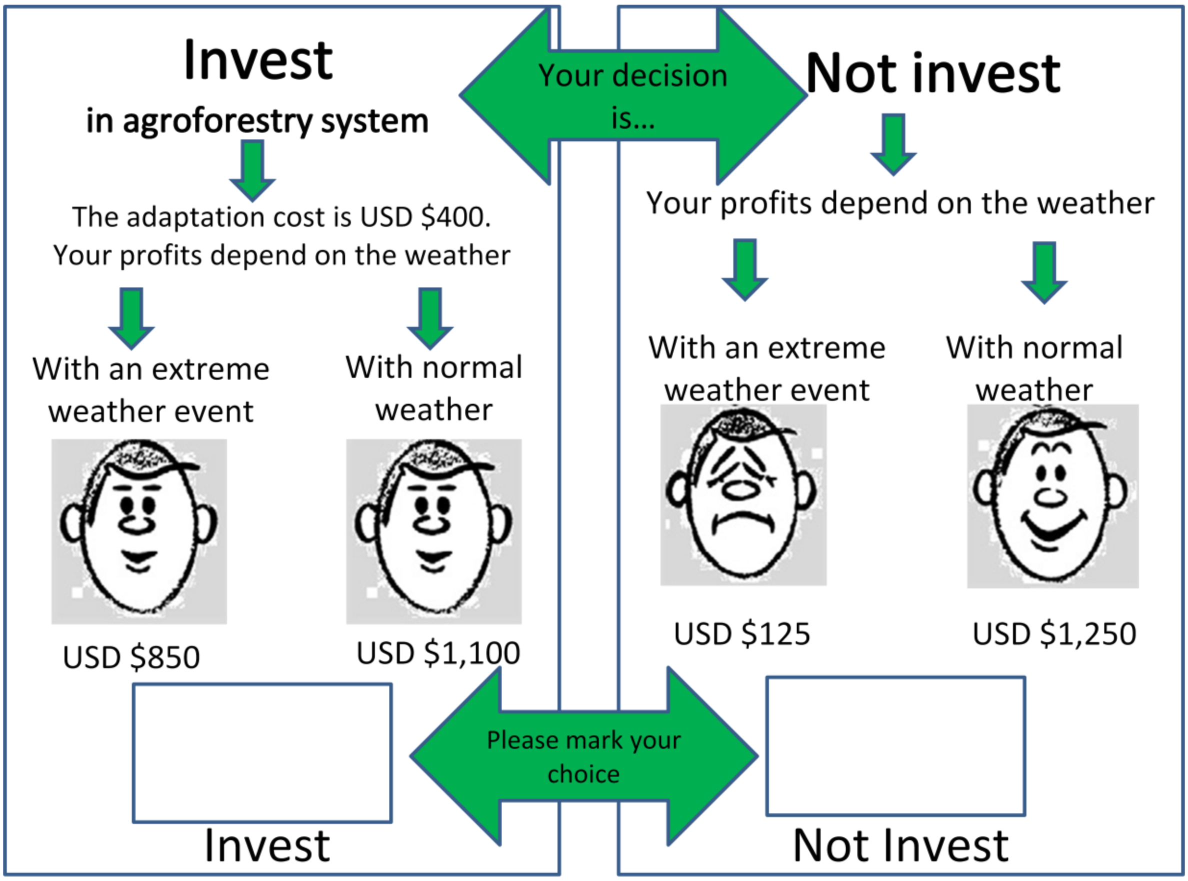
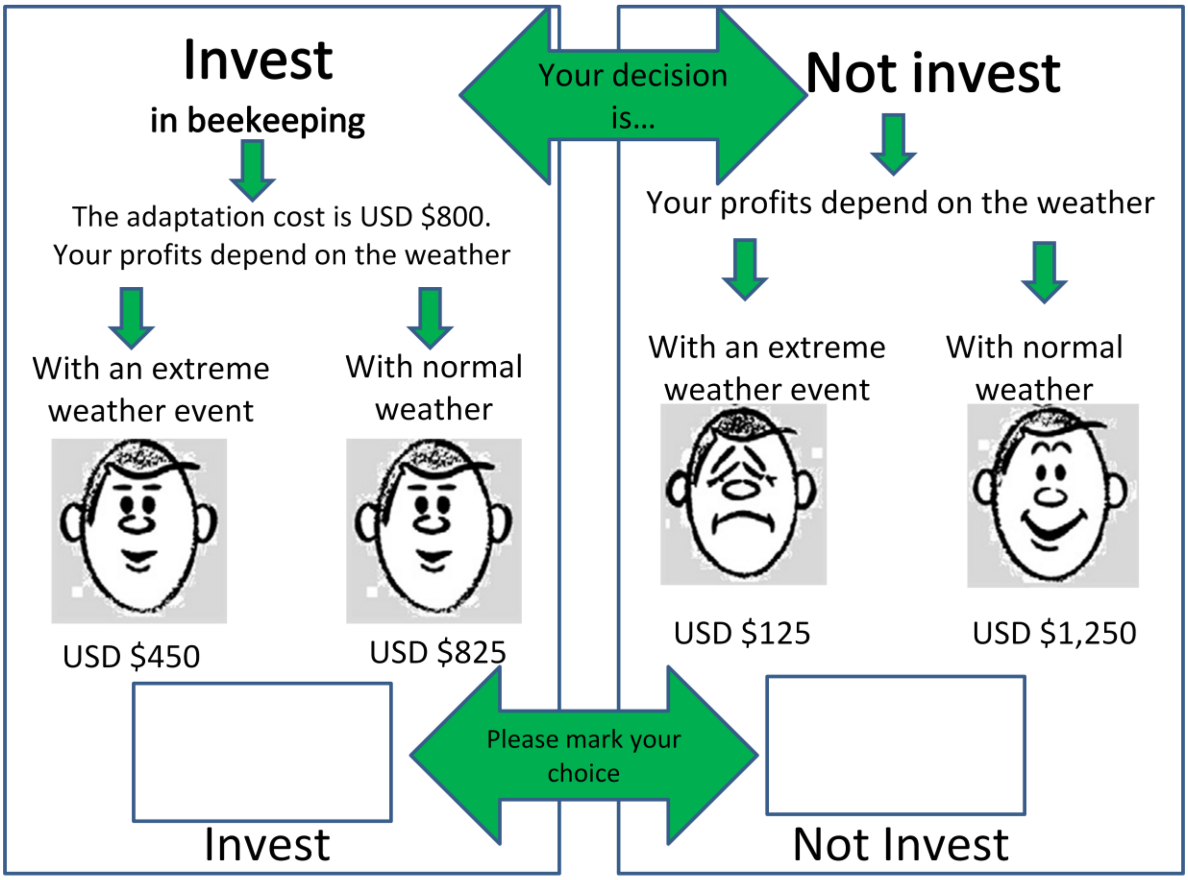
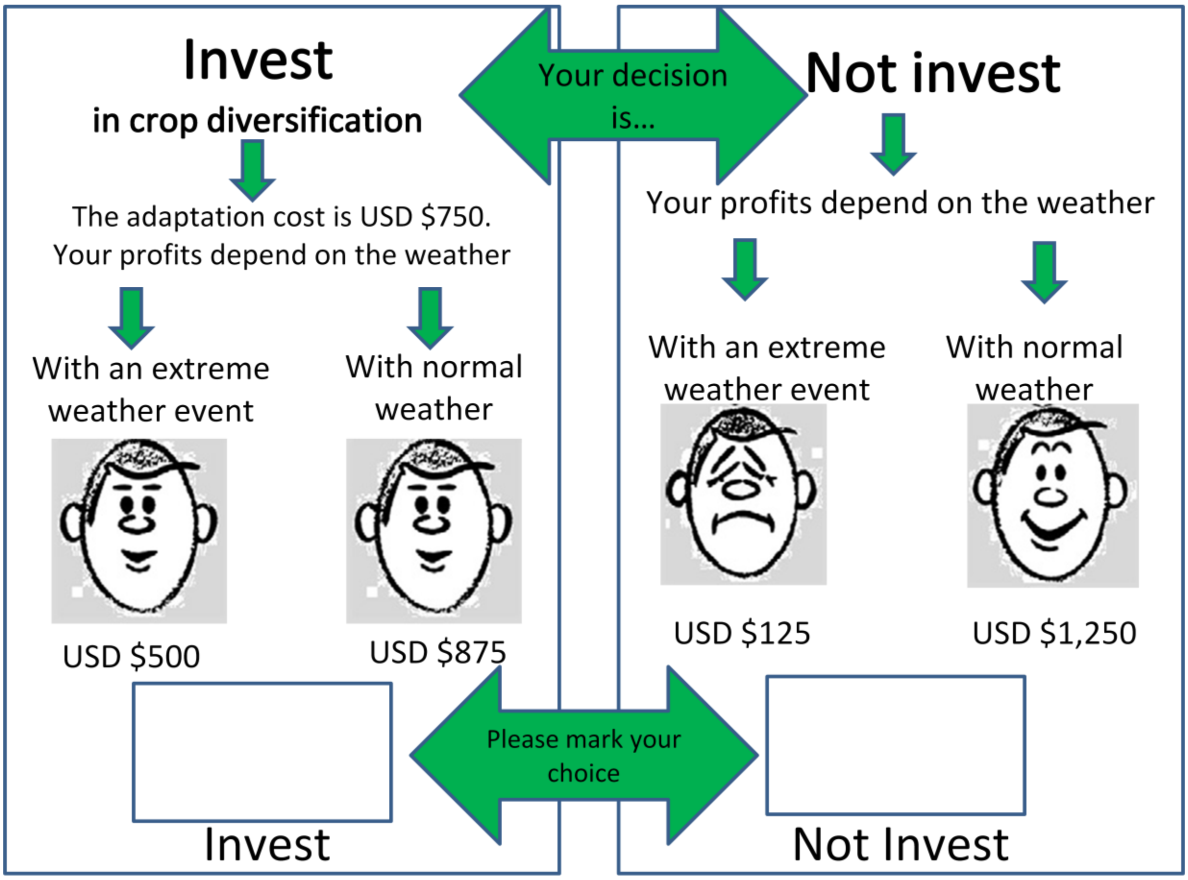
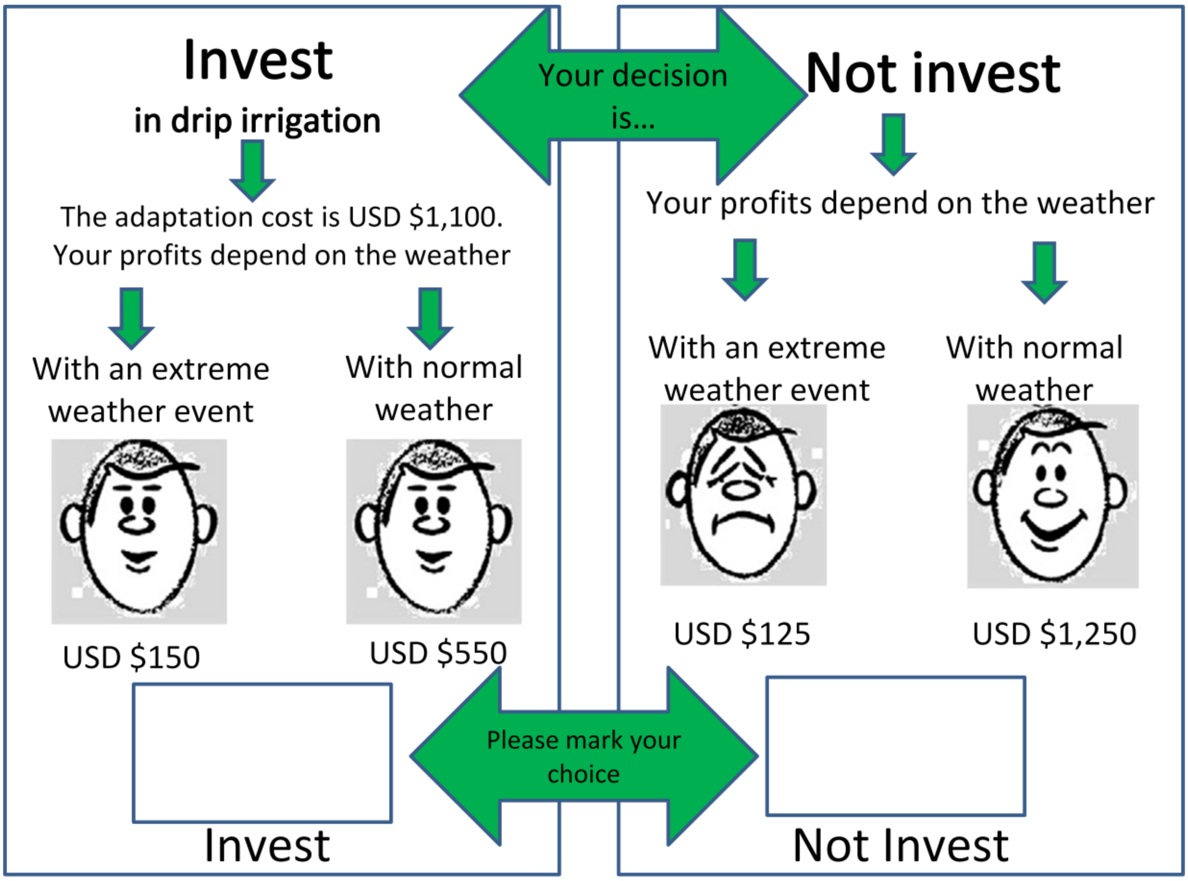
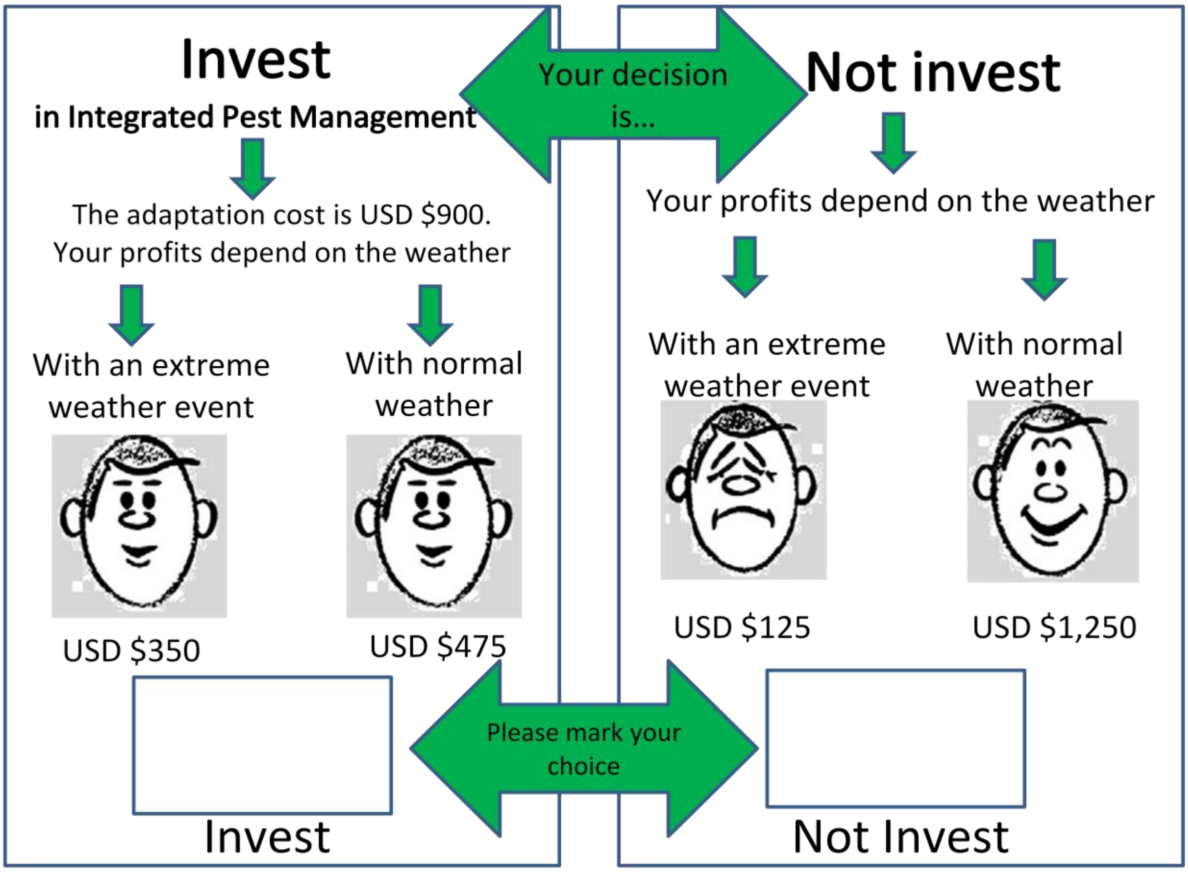
Appendix 1: Decision sheets used in the EEGs

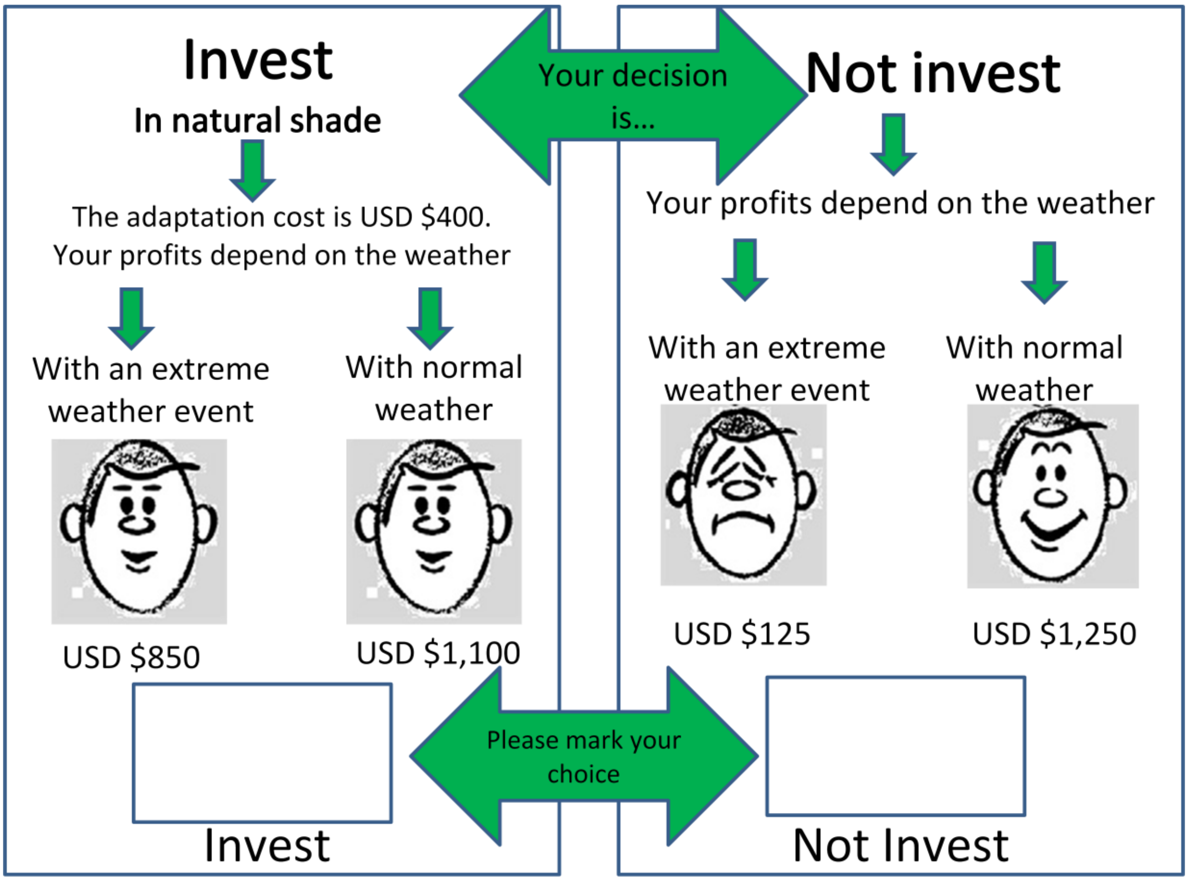


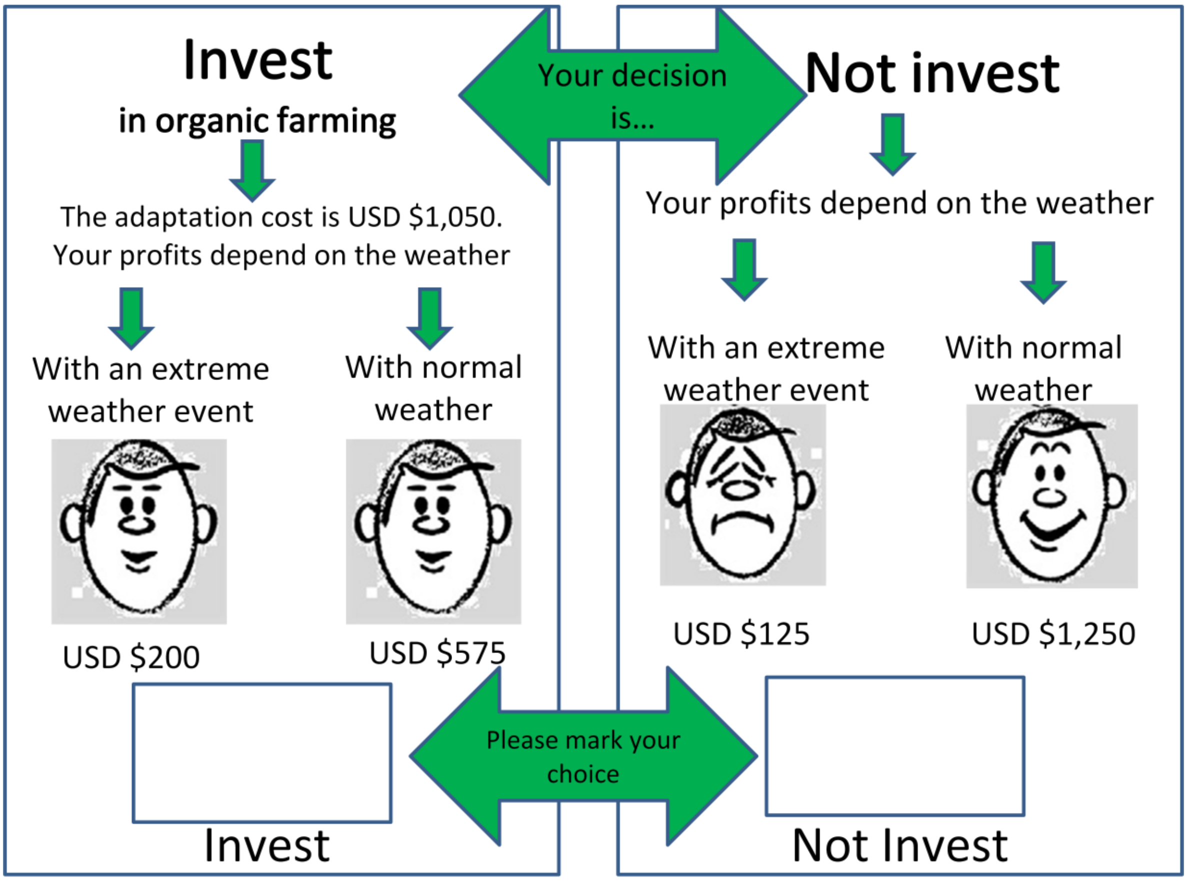


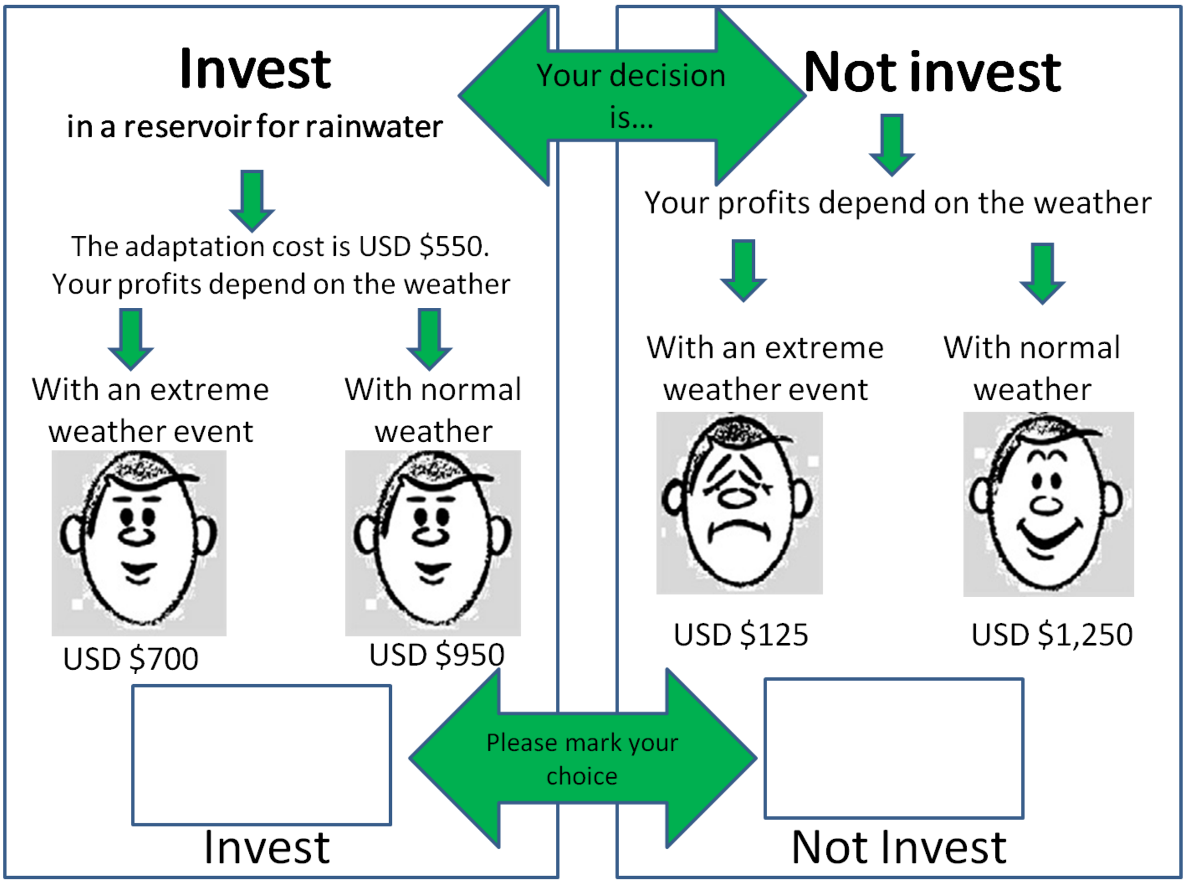

Invest
in crop diversification
The adaptation cost is USD $750.
Your profits depend on the weather
With an extreme weather event
USD $500
With normal weather
USD $875
Invest
Your decision is…
Please mark your choice
Not invest
Your profits depend on the weather
With an extreme weather event
USD $125
With normal weather
USD $1,250
Not Invest

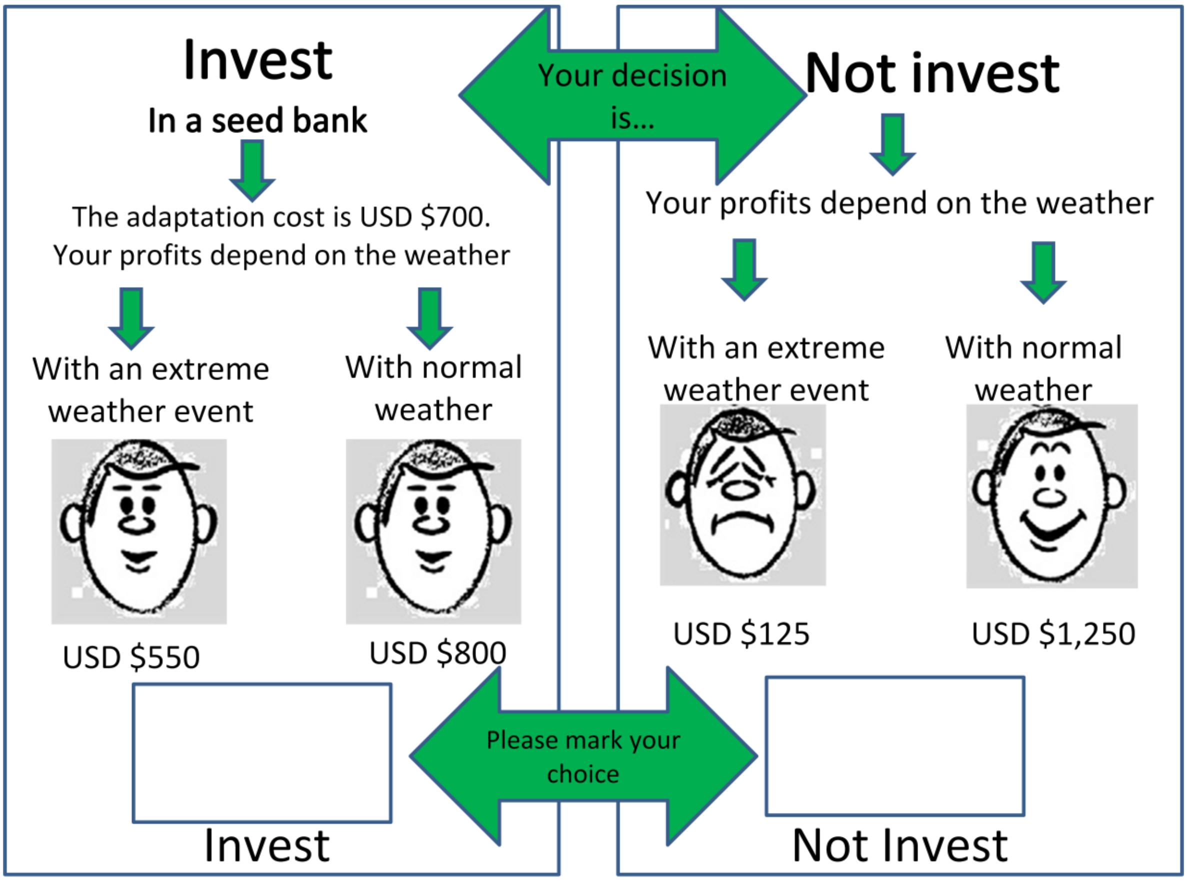

Invest
in drip irrigation
The adaptation cost is USD $1,100.
Your profits depend on the weather
With an extreme weather event
USD $150
With normal weather
USD $550
Invest
Your decision is…
Please mark your choice
Not invest
Your profits depend on the weather
With an extreme weather event
USD $125
With normal weather
USD $1,250
Not Invest

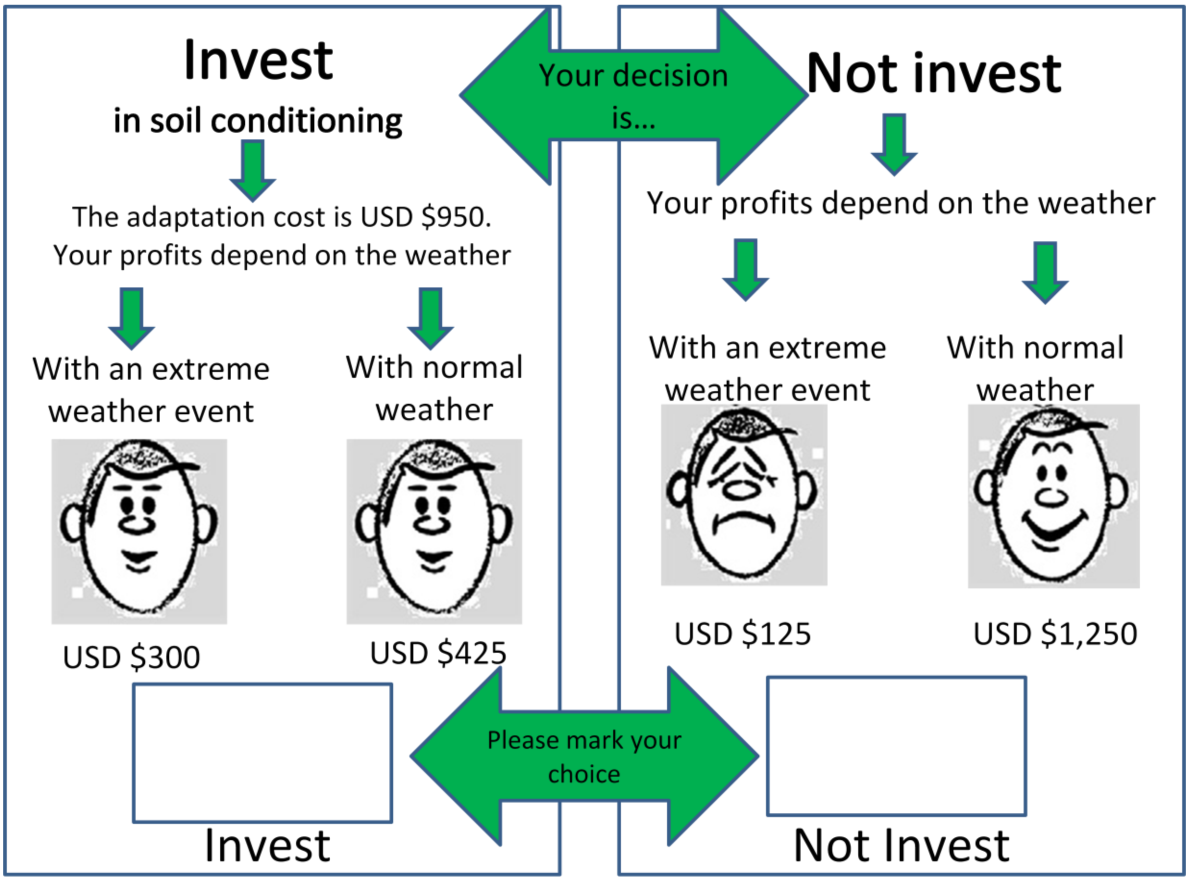

Invest
in Integrated Pest Management
Your decision is...
Not invest
The adaptation cost is USD $900.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $350
USD $475
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Please mark your choice
Invest
Not Invest

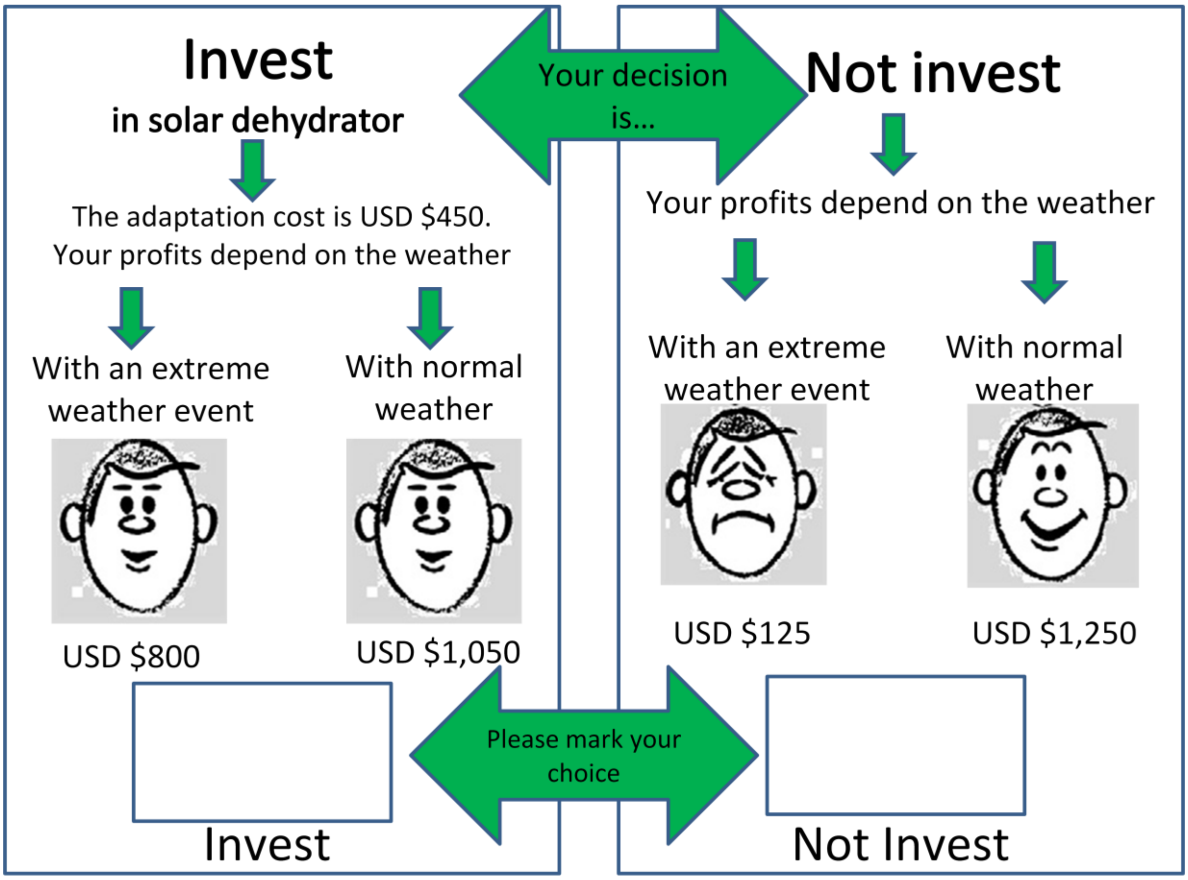

Invest
In natural shade
Your decision is...
Not invest
The adaptation cost is USD $400.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $850
USD $1,100
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Please mark your choice
Invest
Not Invest


Invest
in organic farming
The adaptation cost is USD $1,050.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $200
USD $575
Invest
Your decision is...
Not invest
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Please mark your choice
Not Invest


Invest
in a reservoir for rainwater
The adaptation cost is USD $550.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $700
USD $950
Invest
Your decision is...
Not invest
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Please mark your choice
Not Invest


Invest
In a seed bank
The adaptation cost is USD $700.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $550
USD $800
Invest
Your decision is...
Please mark your choice
Not invest
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Not Invest


Invest
in soil conditioning
The adaptation cost is USD $950.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $300
USD $425
Invest
Your decision is...
Please mark your choice
Not invest
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Not Invest


Invest
in solar dehydrator
The adaptation cost is USD $450.
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $800
USD $1,050
Your decision is...
Not invest
Your profits depend on the weather
With an extreme weather event
With normal weather
USD $125
USD $1,250
Please mark your choice
Invest
Not Invest

Appendix 2: Survey with participants of the Experimental Economic Games

SURVEY WITH PARTICIPANTS OF THE EXPERIMENTAL ECONOMIC GAMES IN THE MUNICIPALITIES OF RIONEGRO AND BERLÍN IN SANTANDER, COLOMBIA

Date ____________________ Interviewer __________________________________ Pace ___________

Group [ ] Player number [ ] Crop ___________

Read this section before beginning the survey to clarify the confidentiality of information: This survey is conducted as part of Project MEBA and it is intended to provide information to find out what adaptation strategies are the most beneficial to farmers to cope with the impacts of climate change. It is important that you know that the information from this survey will be used solely for academic and research purposes and that the answers are absolutely confidential, ie, to be saved and anonymity of each of the respondents will be respected.

1. INFORMATION OF THE RESPONDENT

1.1. Gender: Female [ ] Male [ ] 1.2. Age: [ ]

1.3. What is the highest level of education you have achieved?

Primary school [ ] High school [ ] Technical [ ] University [ ] Postgraduate [ ]

1.4. Please list the people who are part of your household and note whether each contributes to the household income:

Relationship with you	Age	Does she/he contribute to the household income?	
		Yes	No
1.			
2.			
3.			

Relationship with you	Age	Does she/he contribute to the household income?	
		Yes	No
4.			
5.			
6.			

2. REGARDING THE ECONOMIC ACTIVITY OF THE RESPONDENT

2.1. How long have you worked in agriculture? Years ☐ Months ☐

2.2. Are you… Farmer on your own land ☐ Labourer ☐ *Go to question 2.4*
Farmer on a rented land ☐ *Go to question 2.4* Other ______

2.3. How many cultivated hectares do you have? ______

2.4. What is the product that you grow? ______

2.5. How many harvests of this crop do you have a year? ______

2.6. How much income, on average, do you receive from one harvest of this product? ______

2.7. How much money must you invest to produce one harvest of this product? ______

2.8. What are the profits that you get from one harvest of this product? ______

2.9. Do you have any other activity that generates income for you? No ☐ Yes ☐ Which? ______

2.10. The total income of your household (all members included), on average, in one month is:

1. Less than USD 150
2. From USD 151 to USD 250_____
3. From USD 251 to USD 500_____
4. From USD 501 to USD 750_____
5. From USD 751 to USD 1000_____
6. From USD 1000 to USD 2500_____
6. More than USD 2500_____

2.11. Suppose there is a staircase with 10 steps in your municipality, where the poorest families are located on the first step and the richest on the tenth. On what step would you place your family?

1	2	3	4	5	6	7	8	9	10

3. REGARDING THE CLIMATE VARIABILITY AND THE EFFECTS OF CLIMATE CHANGE

3.1. Which of the following weather events most affect your crop? *(You can mark more than one option)*

Frost		Hail		Landslide	
Heavy rains		Drought		Strong wind	

3.2. There are strategies that could help reduce the damage caused by weather events. Would you be willing to make an investment to implement these strategies in your crop?

Yes *Go to question 3.4* No *Go to question 3.3*

3.3. Why not invest in a strategy that allows you to adapt to climate change? *(You can mark more than one option)*

Lack of money		Not believed there are strategies that can help you	
Is not the owner of the land where she/he works		Think that climate change is not as serious	

3.2. Which of the following strategies could help you adapt to climate change? *(You can mark more than one option)*

Agroforestry system		Greenhouses		Reservoirs for rainwater	
Apiculture		Drip irrigation		Soil conditioning	
Crop diversification		Natural shade		Integrated Pest Management	
Fog catchers		Organic farming		Solar dehydrator	

3.3. What strategies did you work in the game with? Strategy 1 ______________ Strategy 2 ______________

3.4. For strategy 1 *(name the strategy)*, in general, did you prefer to invest or not to invest? Invest [ ] Not invest [ ]

3.5. Why did you prefer to invest/not to invest? ____

3.6. For strategy 2 (name the strategy), in general, did you prefer to invest or not to invest? Invest [ ] Not invest [ ]

3.7. Why did you prefer to invest/not to invest?

4. REGARDING THE ACCESS TO FINANCIAL SERVICES

4.1. Have you ever applied for a loan? Yes ☐ *Go to question 4.2* No ☐ *Go to question 4.6*

4.2. Was the loan approved? Yes ☐ *Go to question 4.3* No ☐

4.3. What was the amount of the loan? ____________

4.4. How long was the loan? Years ______ Months ______

4.5. What was the purpose of the loan? ***(You can mark more than one option)***

Housing ☐	Education ☐	Car ☐
Agriculture ☐	Construction ☐	Tourism ☐
Furniture and electronics ☐	Other ☐	

4.6. If you could invest in some of the adaptation strategies through a loan with small payments, would you be willing to take it?

Yes ***Finish the survey*** No ***Go to question 4.8***

4.7. What would be the maximum monthly payment that you would be willing to pay? ____________

4.8. Why not take the credit?

Appendix 3: Interview with a member of the MFI Crezcamos

INTERVIEW WITH AN EMPLOYEE OF THE MICROFINANCE INSTITUTION "CREZCAMOS"

Date ___ Interviewer __________________

Interviewee ____

Position _____ Place __

- How did the initiative to offer microfinance products to farmers arise?

- Why have you decided to choose products that promote adaptation to climate change?

- How do you perceive the receptivity of farmers to microfinance products?

- What factors do you consider limiting farmers' access to the financial system?

- Besides financial capital for investment, what else do you think farmers need to improve the productivity of their crops?

- What could help improve the quality of life of farmers?

Appendix 4: Interview with farmer leaders of the community

INTERVIEW WITH A FARMER LEADER OF THE MUNICIPALITIES OF RIO NEGRO AND BERLIN IN SANTANDER, COLOMBIA

Date ______ Crop ______

Interviewee ______ Position ______

- What are the agricultural practices used by this community? (Organic fertilizers, composting, water conservation)

- How is the normal variation of the weather in this municipality? (frequency and intensity of rainfall, drought, frost)

- What are the main threats and impacts of climate change on crops?

- Is there any authority or organization working with farmers and promoting agriculture?

- How are water resources managed in this region?

- Do you think it is easy to have access to a loan in order to improve the productivity of your crop?

- What does a farmer need for improving the productivity of his crop?

- What does a farmer need for improving his quality of life?